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IMPACT OF ENERGY USE ON THE ENVIRONMENT  
IN ONTARIO

REPORT

Prepared by the members of the Sub-Committee on  
Energy and the Environment for the

ONTARIO ADVISORY COMMITTEE ON ENERGY

MARCH 1973

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## FOREWORD

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## INTRODUCTION

In North America and elsewhere in the industrialized world we have placed a high priority on convenience and consumer goods. The conflicts between consumption patterns, the growth which many people want and the environmental degradation which we all would like to avoid is, perhaps, sharper for the consumption of energy than for any other resource. Everyone wants to use as much electricity as he needs, whenever he wants it, yet, few people like the sight of a power plant with its discharges into the environment or its transmission lines. Similarly, nearly everyone desires an automobile or two for his own transportation, yet no one consciously wishes to contribute to air pollution or traffic congestion. Because of the growing opposition in North America to the location of power plants and opposition to the expansion of freeway systems in our urban areas, it must be concluded that, for an increasing number of people, these services are no longer acceptable, under the terms offered. The general public is becoming aware of the hidden costs of degrading the environment.

The use or conversion of energy completely pervades our daily lives and at the same time poses almost every type of environmental problem we face. There is probably no more important single area for which environmental protection and long-range planning should be emphasized than in the use of our energy resources. Although it is not possible to eliminate all environmental effects from energy use, it is practical to minimize these effects by long-range planning, selective siting, careful design and construction, optimizing operating practices and incorporating new technology as it evolves.

Until quite recently the selection of fuel for any use was only a matter of choosing one with the lowest apparent cost. Our rising environmental concerns have altered the traditional concept of what is desirable. Today, selecting a fuel involves considering the effects on the air, water and land of (1) obtaining it, (2) processing and transporting it and (3) utilizing it. This presents a multitude of complex problems, since the primary energy sources, coal, oil, natural gas, nuclear fuel and hydraulic power have vastly different environmental effects. Consequently, trade-off decisions which should be made between the different energy sources to minimize the environmental impact are not at all straight-forward or easy. Based on the technical trends rough cost estimates may be made for pollution control in the future. However, it is not possible to quantify the hidden costs of pollution and estimate the price of continuing as we have in the past.

There are two general approaches to our environmental problems. The first proposes that technological improvements can be made and can reduce the environmental impact of energy use to tolerable levels. The second approach questions our per capita consumption levels and suggests population be controlled until an ecologically balanced society results. We may in the future have to forego some conveniences and pay higher prices for certain goods and services, including energy if we want a continuing high quality of life in a healthy environment. Present-day public opinion appears to favour the first approach and the bulk of this report is concerned with the means by which this approach may be achievable, inasmuch as it may offer the most palatable strategy for the near future. However, a growing

number of people support the second method, which is now a matter of debate involving a basic change in the structure of our society. This view will probably gain wider acceptance as more and perhaps irreversible changes of the environment are observed.

## I. CONCLUSIONS

### 1. Impact of Energy Resource Development

- (i) Other countries and provinces will feel the need to implement control program on the industries which obtain and process fuel, in order to preserve the quality of their own environment. This will continue to increase the cost of fuel which Ontario purchases from outside the Province over the next two decades.
- (ii) Preliminary studies indicate that the Onakawana lignite deposits may be developed with acceptable environmental impact; however, a complete and detailed investigation should be made before the decision is taken to proceed. The sulfur content of the lignite on an equivalent energy basis is about 1 to 2%; therefore, sulfur abatement may still be necessary if it is used in an urban area as a solid fuel. Lignite gasification near the deposit with appropriate emission controls may be carried out in the long-term with an acceptable impact to the local environment. The gas produced would be an environmentally desirable fuel for Southern Ontario.
- (iii) Detailed information on the ecology of the James Bay area is sparse. It is believed that the environment is much more fragile than Southern Ontario and careful studies are a pre-requisite

to large-scale development of the area.

- (iv) Mining and milling of uranium has produced serious water-pollution problems in Ontario. Improved waste-handling techniques and control methods using existing technology are available and should be promoted. Emission of airborne radioactive substances can also be further reduced with improved practices.

## 2. Impact of Processing and Transporting Fuels

- (i) There exists a potential danger of major oil spills arising from a collision involving vessels transporting oil which can be of catastrophic consequences to the aquatic environment. Although contingency planning to confine, combat and clean-up oil spills are developing rapidly, there remains a high degree of vulnerability associated with oil spills. Oil losses by themselves represent little financial losses to the owners.
- (ii) Although the chance is remote, a failure of a critical piece of equipment at a heavy-water production plant could result in the emission of hydrogen sulfide gas in quantities large enough to cause a danger to life. Siting of such plants should reflect this possibility, and further contingency planning to cope with this situation is needed.
- (iii) Oil and gas pipeline construction, cleaning and operational practices, in the past, have resulted in an impact on land quality due to erosion, the spilling of chemicals, the improper use of herbicides and poor clean-up practices.
- (iv) Enriched uranium and fuel reprocessing are not required for the

CANDU system. However, future fuel requirements or economic conditions could dictate the installation of an enrichment plant to produce refined uranium for light-water reactors in Ontario or for export and the reprocessing of spent fuel rods. Reprocessing and enrichment plants have a high potential for producing air-quality and water-quality problems. Environmental factors should be considered before allowing fuel enrichment or reprocessing in Ontario.

- (v) Refining of petroleum products creates a variety of water- and air-quality problems.

(a) Oil and phenols are the major pollutants of waste streams discharged into the water. Existing waste loading is expected to **decrease** significantly during the next decade as a result of the implementation of improved abatement methods.

(b) Refineries are a major source of hydrocarbon emission into the air and contribute in varying degrees to the total atmospheric emission of sulfur oxides, carbon monoxide, nitrogen oxides and particulates. In addition, refineries may be an irritating source of malodorous compounds. Refineries are prone to violate sulfur dioxide and dustfall impingement standards. The contribution to total carbon monoxide emission is small and may be expected to decrease as uneconomic operations are phased out.

(c) Hydrocarbon, sulfur dioxide, particulate and nitrogen oxide emission may be expected to increase as refinery capacity increases. Sulfur dioxide and particulate emission may be controlled so that the Provincial air quality standards

are not exceeded in the future. Also hydrocarbon emission may be reduced significantly.

(d) Emission of malodorous compounds is a source of many complaints. Good household practices and exercising good care in all operations could potentially reduce this problem. Due to the complexity of refinery operations, process upsets which may result in excessive pollutant emission into the air occur relatively frequently.

(e) Because of the large quantities of oil handled by refineries, there is a significant potential for accidental oil spills. Moreover, the distribution system of refinery products is a large source hydrocarbon emissions into the atmosphere.

### 3 Impact of Utilization of Fuels and Energy

#### 3.1 Electrical Power Generation

##### 3.1.1 General

- (i) The charters or terms of reference of electrical-power generation organizations in North America, both public and private, are primarily concerned with producing electricity at low cost, and with economic development. As a result, the price of electric power like many other consumer goods, does not reflect its total cost to the public. A variety of water-quality, air quality and land-use effects give rise to real, but hidden costs.
- (ii) In the past five years power-generation companies have begun to recognize their environmental impacts and have taken measures to reduce them. However, the necessary techno-

logy is still not available to resolve many of the environmental problems of electrical power production. As a result, further environmental degradation will occur over the next decade and perhaps beyond due to the exponential growth in electrical production.

- (iii) The existing degradation of environmental quality, due to energy use, is localized in extent, but will probably become more widespread with increasing urbanization of Ontario. The extent to which this trend may be overcome in the 1980's will depend upon the incentives, forced or induced, to produce "clean power".

#### 3.1.2 Hydroelectric Power

Electrical power generation from falling water, produced by damming and diverting, has disrupted fish and aquatic populations, and in some cases reduced aesthetic values. Careful and complete ecological studies should be carried out prior to development of further water resources in Ontario.

#### 3.1.3 Fossil-Fuel Electric Power

- (i) Fossil-fuel generating plants located in large urban areas represent a major contributor to degraded air quality. Solid particulates are effectively controlled in Ontario, and the control equipment is now an accepted part of the generation equipment. Regulatory agencies are primarily concerned, at present, about the sulfur

dioxide emissions from fossil-fuel plants. There is also increasing interest in future control of the oxides of nitrogen as well as heavy metals emission.

- (ii) Sulfur emission controls will be necessary in some generating stations to achieve the specified ambient  $\text{SO}_2$  levels over the next two decades. Substituting low-sulfur fuel and mechanical or chemical coal cleaning offers little long-range potential for reducing sulfur emissions. Flue-gas desulfurization may be practical by the end of this decade and provide sufficient sulfur removal which together with the proper siting of plants will allow the ambient  $\text{SO}_2$  air standards to be achieved through 1991. Flue-gas desulfurization will increase power costs by 10 to 25%. Coal gasification appears to have the best long-range potential for reducing sulfur emissions. The United States has undertaken a significant effort to develop this process as a means of producing an environmentally clean fuel. The technology, if not the coal gas itself, may be exported to Ontario.
- (iii) Natural gas is an environmentally desirable fuel. Its limited supply would appear to dictate that it be conservatively used in applications where other sulfur abatement methods would be prohibitively expensive or not presently available.

- (iv) Controls of the emissions of the oxides of nitrogen from many stationary sources may be expected by the end of this decade. The necessity of controlling this air pollutant from power generation plants may be largely dictated by the success of the abatement program underway for automotive sources. Reductions in these emissions up to perhaps 50% can be presently achieved, but technology is developing very slowly for the higher degree of removal of oxides of nitrogen.
- (v) Coal- and oil-fueled plants emit heavy metals and radioactive substances into the air due to impurities in fuel. At the present time, the contribution of these pollutants from fuel burning cannot be distinguished from the background ambient level arising from other sources. These substances may have significant health and environmental effects and may represent a potential long-range hazard.
- (vi) Apart from waste-heat disposal, fossil-fuel plants impact water quality through the addition of slimicides and other chemicals to the water, by drainage problems around coal storage piles and by minor oil spills. Also, wind-blown coal dust gives rise to air-quality problems. All of these problems should be manageable in the future.

#### 3.1.4

##### Nuclear Electric Power

- (i) The risk of a severe environmental impact due to a

catastrophic failure at a nuclear power station is very small. At present it is not possible to weigh it in comparison to the long-term environmental effects of fossil-fuel plants.

- (ii) The water and air radioactive emission of nuclear plants on an annual basis are only 1 to 10% of the current allowable release limits. The present limits provide the possibility for less rigorous control of emission of radioactive products by the industry which could result in needless exposure of the public to radiation.

#### 3.1.5 Disposal of Thermal Wastes

- (i) Both nuclear and fossil-fuel plants must dispose of up to 70% of their input energy as waste heat. At the present time, this is primarily achieved in Ontario by discharging heated cooling water into lake waters. The discharge of waste heat into the environment will increase proportionally to the increase in energy consumed by electrical power generation facilities. Moreover, the quantities of cooling water needed are tremendous, and there is concern that their use may alter circulatory patterns in some lake areas.
- (ii) Although the utilization of waste heat is highly desirable, the prospects of its beneficial use with existing plants are dim except in very limited ways. For future power stations, a completely revised plant design concept would

have to be integrated with a particular concept for waste-heat utilization. Cooling water would probably have to be discharged at higher temperatures and consequently the plant efficiency considerably reduced to find reasonable uses of waste heat.

- (iii) Up to the year 2000, significant increases of the temperatures of Lakes Ontario, Huron and Superior, due to the rejection of waste heat, may occur near the shoreline in the vicinity of once-through, water-cooled generating stations. Shoreline regions, however, are particularly important to the ecosystem of the entire lake. The future siting of plants, using once-through cooling, may alter certain desirable aspects of the aquatic environment up to 3 to 5 miles from the plant. However, in certain areas the discharge of heated water can also provide beneficial effects by improving circulation patterns, and by increasing the recreational potential, if other pollutants are absent.

Any further addition of waste heat in the western and central basins of Lake Erie is undesirable. Several portions of Lake Erie already have serious water-quality problems which would be compounded by further heat addition. There is a possibility that the International Joint Commission may recommend a restriction on waste-heat

disposal and/or temperature rise in the waters of the Great Lakes. If accepted by Ontario this would significantly affect present and future power stations located on the lakes.

- (iv) Large evaporative wet cooling-towers may be an alternative to once-through cooling systems. They are not expected to cause fog or ice problems except in their immediate vicinity, when unusual atmospheric conditions exist. A buffer zone around the station site would minimize the impact of this problem. The winter temperatures in Ontario could result in larger and persistent vapour plumes. The environmental impact of such plumes should be studied.

#### 3.1.6

##### Impact of Land Use

- (1) There is increasing public concern about the "aesthetic impact" of freeways, transmission lines, tall stacks, etc. There will be concern about the aesthetics of cooling towers. Public education as to the alternatives may increase their acceptance. Transmission line rights-of-way or limited access highways may use land areas up to about 100 acres per mile. Energy corridors (combined access of transmission lines, pipelines, rail lines) may make better overall use of the land, but are difficult to achieve. Inasmuch as fossil-fuel plants contribute greatly to urban air-quality degradation

and all pollutant emission cannot be adequately controlled at present isolated power stations with the attendant price of longer transmission lines are the better environmental strategy provided that the transmission lines are planned for minimum impact.

- (ii) Completely cleared rights-of-way have adversely affected forest, recreational, wildlife and historic areas. Improved planning considering scenic and aesthetic values, wildlife habitat and multi-purpose uses is possible at this time.
- (iii) Hydroelectric development has decreased the mileage of "wild rivers" in Ontario, altered aquatic life and migration, changed river beds and altered the surrounding landscape. Some water-power developments, however, have been beneficial in providing additional recreational values in the areas involved.
- (iv) The disposal of radioactive wastes, as well as chemical compounds formed in future flue-gas cleaning methods, will produce increasing problems in the future. Immediate attention should be given to the long-range radioactive disposal problems for Ontario.

#### 3.1.7

##### Comparisons

- (i) The environmental impact of nuclear, fossil-fuel or hydro power plants is a matter of local and regional concern. It is not possible, at the present time, to adequately control all of their environmental problems

by application of existing technology. Consequently, conservation of electricity can reduce the growing degradation of our environmental quality. Advertising and public education directed toward conservation of electricity decreases the demand 1 to 2% for one U.S. power company. Although this is small in terms of total capacity it represents 15 to 20% decrease of the mean growth rate of 7% per year.

- (ii) Hydroelectric plants cannot satisfy the future demand for power. Thermal plants using natural gas have a comparatively low environmental impact, but the limited supplies of natural gas preclude their use in the future except in special problem areas.
- (iii) The basic choice for power generation which can supply the need at present is between (1) nuclear, (2) coal - or (3) oil-fuel plants. A CANDU nuclear plant appears to offer the lowest overall impact to the environment of these choices when all factors are compared.
- (iv) It is difficult to compare the hidden cost of pollutant emission from power generating sources with the cost of environmentally clean energy. All of the needed information is not available for Ontario. However, as one example, in the U.S.A. it has been estimated that total cost to human health, vegetation, materials and property is 10¢ per lb of sulfur dioxide emitted.

### 3.2 Transportation Uses

### 3.2.1 Automotive

- (i) In terms of total tonnage of pollutants emitted into the air, automobiles and trucks represent the largest single type of air pollution source. They account for about half of the total air pollutants in almost all large urban areas in North America. However, their primary contribution is carbon monoxide which is, in general, not as harmful as other pollutants. Automobiles also emit large quantities of hydrocarbons, nitrogen oxides and lead into the air and may contribute substantially to the formation of photochemical smog in urban areas under certain meteorological and sunlight conditions. Airborne lead from automotive sources constitutes a long-term health hazard if not abated. Also, lead fall out from automotive sources constitutes a potential health hazard to humans due to contamination of fruits, crops and vegetable grown near highways of high traffic density.
- (ii) Automotive vehicles also cause in an indirect way a number of other pollution problems. The disposal of waste oil is of some concern. In large urban areas, waste oil is collected and returned to refineries, but oil disposal in small communities is a problem. Oil and grease dripping from vehicles onto the streets and roads can be washed into the waterways. The practice of snow disposal into water bodies together with the increasing use of salt on the roads to keep them passable is becoming of increasing concern as to the effect of chlorides, suspended solids,

organic matter and lead from this source on water quality.

- (iii) A number of emission controls have been installed on automobiles since 1968. These have been directed toward the reduction of hydrocarbon and carbon monoxide emissions and the emissions of these pollutants have been reduced upto 80% on present-day new vehicles. Without further controls the emission of automotive pollutants will more than double during the next two decades. Abatement of the emissions of the nitrogen oxides is the remaining problem and subject of considerable controversy.
- (iv) Due to federal legislation automotive pollutant emission will be significantly reduced during the next fifteen years, but will increase again after 1985 as a result of an ever increasing vehicle population. The Canadian Government has adopted the same standards and guidelines as the U.S., which will require extensive abatement of nitrogen oxides on 1976 models. The U.S. automotive abatement program in part is based upon reducing the potential for photochemical smog. The abatement of nitrogen oxide emissions will in all likelihood require catalytic converters. This will add about \$300 - \$600 to the cost of the 1976 models, and represent a total cost of about \$100 million to new car buyers each year in Ontario. Photochemical smog does not routinely occur in Ontario or elsewhere in Canada. Consequently, there is a debate as to whether controls needed in Southern California are needed in Canada or elsewhere in the U.S.

- (v) Natural gas or propane powered vehicles have reduced exhaust emissions. The use of these fuels in urban areas is economically feasible and desirable especially for fleets of vehicles. An extended use of bicycles within the city cores will reduce traffic congestion and automotive emissions in these areas on a seasonal basis.
- (vi) Alternatives to the Internal Combustion engine (ICE) are being explored. However, no large scale replacement of the ICE may be expected until the 1980's. The concept of a low pollution urban vehicle is being pursued. This topic is more fully reported in another study carried out for the Advisory Committee on Energy.
- (vii) Vehicles also give rise to serious noise problems both in urban and rural areas. Noise control is inefficient unless noise emission is controlled at the source. Noise barriers adjacent to busy highways have proved to be ineffective. Unless effective noise controls are implemented, noise levels in all communities may be expected to increase in the future as the population of vehicles increases. Moreover, the serious noise problems adjacent to freeways, busy streets, stop and go truck routes and airports will also increase.
- (viii) Automobiles are the least efficient means of urban transportation. Their widespread use by urban commuters results in heavy rush-hour traffic and a significant contribution to the overall air pollution in urban areas. The impact of the automobile in rural areas is not as serious as in urban areas by virtue of their lower numbers and lower traffic density.

### 3.2.2 Aviation

- (i) The emission of pollutants by aircraft in an urban area is only 1 - 2% of the total pollutant emission by transportation sources. Odors and particulates (smoke) at airports and vicinity are the most noticeable pollutants. The environmental impact of aircraft flying at high altitudes is not fully understood. However, increased cloud cover and increased ultraviolet radiation at the earth's surface are two of several possibilities which could affect weather and the balance of nature.
- (ii) Aircraft noise is a major problem in residential areas close to descending and ascending aircrafts. Aircraft noise will remain high, despite several years of research directed to reduce it. Land-use planning and control appears to be the key to achieving an acceptable solution to aircraft and airport noise.

### 3.2.3 Mass Transportation

- (i) The need for future reductions in total pollution output from automotive sources can best be met by increasing efforts to provide mass transportation systems of low-pollution potential in large urban areas. It is clear that rapid mass transportation systems designed with low noise levels in mind can also effectively reduce urban noise levels.
- (ii) Mass transit systems must be faster, cheaper and more comfortable to the consumer than the use of his own automobile in order to provide an incentive for an increased use

of the mass transit system. Existing hydro easements, rail lines and other rights-of-way may be combined for the development of urban mass transit systems without exorbitant cost of land.

- (iii) The continued growth of the city and the aggregation of people in the downtown core, due to the construction of large commercial buildings, will place ever increasing demands on urban transportation. There are limits to growth of the present mass transit system in the Toronto area, unless a new innovative approach to mass transportation is taken. At present the Ministry of Transportation and Communications is conducting a study of innovative approaches to mass transit systems. Such measures could play a significant role in reducing pollutant emission from automotive sources.
- (iv) Planning and expansion of the existing mass transit systems in nearly all cities including Toronto has been consistently inadequate in relation to the rapid growth of the downtown city core.
- (v) High speed trains are much more efficient and have a lower overall environmental impact than airplanes for moving people or freight between urban areas.

### 3.3 Residential and Commercial Uses

- (i) Residential and commercial uses accounted for about 30% of the total energy consumption in Ontario in 1971, and for about 45% of the electrical energy consumption. In the household the major consumption of energy is for space

heating, water heating, lighting, and air conditioning. Commercial uses are predominantly for space heating or cooling and lighting.

- (ii) The pollutants being emitted by the use of primary energy for residential and commercial purposes are mainly sulfur dioxide and nitrogen oxides. In Metropolitan Toronto despite a growing consumption of energy the sulfur dioxide emission will almost remain constant due to a more widespread use of low-sulfur fuel. The emissions of the nitrogen oxides from residential and commercial sources, however, will increase by 250% by 1991. In other urban areas of Ontario, where sulfur restrictions for fuel oils are not in effect, both sulfur dioxide and nitrogen oxide emissions will increase with increasing consumption of fuel
- (iii) In Metropolitan Toronto residential and commercial uses of primary energy by themselves did not result in violation of the provincial ambient air criteria in 1971. Since the emissions from residential and commercial sources are relatively close to the ground, dispersion of the emitted pollutants is poor. For all practical purposes the use of low-sulfur fuel is the best sulfur dioxide abatement strategy for these hundreds of thousands of air pollution sources. Flue-gas cleaning abatement systems are not practical for residential sources due to their very large number and large variety of installations.

- (iv) It is possible to increase the combustion efficiency of residential and some types of commercial building heating systems by proper service and maintenance. Many units are poorly maintained. The present schedules of maintaining and servicing of these systems can be significantly improved.
- (v) Insulation standards for electrically heated homes are more stringent than for fossil-fuel heated homes in order to make electrical heating economically competitive. Consequently, there is considerable room for improvement in the standards for thermal insulation in residential and commercial buildings heated by other means. Better insulation will decrease the amount of energy required for both heating and cooling and therefore may potentially lower the impact that residential and commercial heating has on the environment.
- (vi) Many factors affect the environmental impact of consumption of energy by household and commercial sources. It is undoubtedly easier to control the emissions from large central plants than it is from numerous small homes. Also, many furnaces are poorly maintained and adjusted and emit more pollutants than necessary. On the other hand, electrical power generation utilizes the energy resource less efficiently and emits large quantities of sulfur dioxide and oxides of nitrogen with little immediate prospect of

abatement. However, at some future time, larger portion of the generating system is nuclear, it may be in the public interest to promote electric heating and cooling. In the meantime, urban air quality will become progressively degraded due to the increased use of fossil fuel.

(vii) Some studies have concluded that electrical heating produces a greater environmental impact now, but it could provide the best heating means from the environmental viewpoint by the 1980's. The utilization of fossil fuels other than coal in residential and commercial applications does not give rise to direct water quality problems, waste disposal problems or other factors affecting land use and natural resources.

(viii) The use of waste heat from thermal power stations and other boiler installation is often mentioned as an energy resource for area heating. This is not practicable with existing systems, but is a possibility in the design of a self-contained total energy system in new towns or large buildings. There exists a needless wastage of energy which could be reduced through a program of energy conservation and efficiency.

#### 3.4 Industrial Uses

(i) Many industries create significant environmental problems, however, of most of these problems are not primarily associated with the conversion or use of energy resources by

the industry. It is difficult to accurately assess the impact attributable to the conversion and utilization of energy by the manufacturing industry.

- (ii) The environmental impact of fossil-fuel energy use by industry in general constitutes only a relatively small portion of its total impact on the environment. Air- and water-quality problems attendant to energy use by industries largely arise from the combustion of fossil-fuels and are similar to those associated with the generation of electrical power from fossil-fuel. Coal, whether used directly for generation of energy or for the production of coke and coke oven gas is presently the largest source of pollutant emission.
- (iii) The production of coke needed for metallurgical processes results in air-quality problems due to emissions of particulate matter and sulfur dioxide into the atmosphere. These problems occur in the steel producing centers in Ontario and are not yet fully resolved. Due to the present design of the coke ovens and their inherent operation, long-term modification or process changes are needed to abate their present emissions. Coke production also creates a variety of water-quality problems due to discharge of phenols, ammonia, sulfides, and other compounds. In addition, the quality of the water may be decreased by increasing the chemical oxygen demand through the discharge of waste streams.

- (iv) While industrial emissions of  $\text{SO}_x$  and particulate matter can be controlled to meet provincial air quality criteria, no efficient control technology for nitrogen oxides is available for many emission sources at present. Therefore, emission of oxides of nitrogen is expected to increase as the energy consumption increases. As a result, air quality criteria for the nitrogen oxides will be exceeded in the future more frequently in wider and wider areas unless industrial growth is restricted in selected areas.
- (v) Emissions of particulate matter and sulfur dioxide by industrial energy consumers in the Toronto area have notably decreased in the past three years. Existing abatement programs will effect additional reductions of these pollutants in the future. Other areas are not as well controlled as yet. Natural gas is needed by some industries both for process requirements and for air pollution control. These uses should be restricted to applications where other fuel use and emission control technology is not feasible.
- (vi) Most industries are acutely aware of costs and efficiency. This awareness can be used to promote conservation of all resources including energy. Policies designed to enhance the reuse of articles, such as containers for liquids, recycling of wastes containing paper, glass, plastics and metals could effectively reduce the energy requirements

of many industries and thus indirectly reduce the pollution potential of these industries. In addition substantial improvement in energy efficiency and conservation of non-renewable resources could be achieved by the manufacture of goods of longer durability.

### 3.5

#### Pecreational Uses

- (i) The consumption of energy for recreational purposes is minor compared with other energy consumers. However, its impact on the environment is believed to be by far greater and damaging than its relatively small use would indicate. The extent of damage to aquatic and wild-life and the natural environment is difficult to estimate due to the vastness and remoteness of some affected areas.
- (ii) The introduction of fuel into the water, especially in high-intensity use areas, such as adjacent to marinas and boat landings, can result in oily scums and oil films on the surface of the water. This is aesthetically detrimental and lowers the water quality. Aquatic life has been shown to be adversely affected by these films, both at the surface and below. Greatest stress is placed on surface breathing organisms.
- (iii) The recreational use of high-powered outboard motors on small lakes and some rivers causes erosion of shores and banks and interferes with the reproduction of certain species of wildlife. It is also a cause of a growing number of complaints due to excessive noise emission and the danger of swimmers.

- (iv) The use of snowmobiles has opened up a new winter recreational activity with benefits to the recreational industry in Ontario. The recreational use of snowmobiles results in adverse impacts on forest and plant communities, fish and wildlife, people and private property due to excessive noise, snow compaction, disturbance of wildlife, property damage and injuries to people.
- (v) Motorized recreational vehicles such as trail bikes, dune buggies and air cushion vehicles have made it possible to travel to formerly nearly inaccessible areas. The use of such vehicles imposes environmental stress on undisturbed wildlife habitat areas, plant communities and shores and banks. Increased erosion, damage to trees and plants, littering, noise, additional fire hazards are serious problems. The regulation of the recreational use of such vehicles to selected areas is necessary.

4.

#### Legal Aspects

- (i) Environmental legislation enacted by the Province of Ontario is the most extensive and comprehensive existing in Canada. The federal program is just getting underway and its scope and impact cannot yet be foreseen.
- (ii) The United States has enacted or is considering several novel measures including (1) mandatory preparation of environmental impact statements that become part of the public record before a project or program is undertaken, (2) taxing certain types of pollutant emissions or fuel additives, (3) setting maximum emission levels from fossil-fuel power

generation stations, some industries, and automotive vehicles and (4) establishing rules for power plant siting with public hearings.

5. Environmental Quality - 1991

- (i) In order to maintain reasonable air quality in Ontario to 1991, fossil-fuel plants should be sited no closer than 30 miles apart and at least 30 miles from the areas of (1) the Toronto region, (2) Hamilton, (3) Windsor, (4) Sarnia, (5) Sudbury and (6) other special areas until extensive pollutant control systems become available and are used.
- (ii) The strategy of abatement and control of air and water pollutants from all sources is highly preferred over the strategy of dilution.
- (iii) The water quality in the Great Lakes in the years of 1991 will largely depend upon the Canadian and American effort undertaken in accordance to the recommendations of the International Joint Commission.

6. Longer-Range Implications

- (i) There are definite environmental limits to growth patterns which induce a stress on the environment, including the exponential growth of energy consumption.
- (ii) Modest climatic changes are now occurring in urban areas. This trend will continue and cover wider and wider areas. Global climate changes of major proportions are not likely by the end of this century but appear to be a distinct

possibility in a hundred years or so.

- (iii) A complex computer model of global dynamics by Jay Forrester predicts some disturbing consequences by the middle part of the next century in which the growth of the global society is limited by the depletion of natural resources or by a "pollution crisis." A stable global situation according to his model will only result by some form of a "zero growth" society. His model is based upon many assumptions which are currently being questioned and investigated; however, it is receiving world-wide attention.

## II RECOMMENDATIONS

An assessment of the environmental impact of obtaining, processing and utilizing energy resources in Ontario has resulted in the following recommendations:

1. Decision-Making and Regulation

1.1 Environmental Impact Statements

It is recommended that the Ontario Government establish a policy of requiring that Environmental Impact Statements be completed and evaluated before the implementation of any new program or projects which would significantly affect the environment. This requirement is specifically recommended for all projects involving energy use or conversion both public and private such as the installation of power generation stations, the routing of transmission lines, the development of the Onakawana lignite deposits and further development of uranium resources, etc. It is also recommended that this policy be adopted in the planning of new freeways, airports, giant urban complexes and similar projects because of the consequent effects that these developments have on the environment. Moreover, it is suggested that Environmental Impact Statements be used to govern private industrial development insofar as they do not comprise the propriety rights of individual companies. The proposed Environmental Impact Statements would establish the need for the project, predict environmental consequences, and indicate the alternatives examined. The statement must play a real part in the decision-

making process and should not be prepared merely to justify decisions already made.

1.2. Public Involvement

It is recommended that the fact-finding and decision-making processes for new programs, their environmental implications, and the alternatives be shared with the public. The Environmental Impact Statements and comments on them from government agencies should become public information and some procedures established whereby the public and citizen groups can express their views in an effective manner. One exception would be that the proprietary rights of private business, patent information, and other factors affecting their competitive position would not be disclosed to the public.

1.3. Continuity and Review

It is recommended that some mechanism be established whereby there is (a) a continuity and assessment of policy with regard to environmental protection and (b) a review process for existing plants and installations. The review process should take place when required at the option of the regulatory authority assigned the responsibility for impact statements and may include the preparation of a modified form of Environmental Impact Statement and a public hearing.

1.4. The Role of Existing Regulatory Agencies

It is recommended that the existing regulatory agencies of the Provincial Government (principally the Ministries of the Environment, Natural Resources, and Health) continue to establish the criteria for achieving and improving the quality of our environ-

ment in all respects. There is, however, a need to co-ordinate the activities and responsibilities of these agencies with each other and together with other Provincial commissions, committees and task forces on matters such as:

- (a) site environmental studies
- (b) ecological studies
- (c) evaluation of abatement methods
- (d) monitoring programs
- (e) all other programs of common environmental interest:

Moreover, it is recommended that Ontario continue its efforts to establish multilateral criteria and control programs with appropriate States to improve the environmental quality in international boundary regions.

#### 1.5. Conservation

Energy use in most of its forms causes a significant impact on the environment. Increasing consumption patterns suggest that the impact will become more serious in the future. Reduction of the unnecessary consumption of our energy resources could provide an effective abatement strategy. Consequently, it is recommended that the Ontario Government take stronger steps to meet its commitment of ensuring that energy is used as efficiently as possible. It should consciously encourage the most efficient uses of our energy resources in all sectors of society and ensure that the price structure adequately reflects the benefits to society of employing the most efficient energy source.

The advertising and marketing policies and rate structures of the energy industries could be designed to encourage conservation of energy by discouraging the unnecessary demands for inefficient energy.

2. Implementation of Recommended Policies for Decision-Making and Regulation

It is recommended that a specific procedure or organization be identified to carry out the policies recommended above. This might be achieved in a number of ways, but two specific suggestions are outlined below:

- (i) The Minister of the Resource Development Policy Field or the Minister of the Ministry of the Environment should be responsible for implementing the administration and co-ordination of the Environmental Impact Statements, utilizing Ministers and personnel in various Departments in his policy Field, as well as from other Policy Fields. He would request the preparation of Environmental Impact Statements for existing installations when deemed necessary in consultation with other Ministers. After the Environmental Impact Statement is prepared by the submitting agency, it is circulated by the Minister or his designate to appropriate governmental agencies in all Policy Fields for comment and evaluation. He would also have the responsibility for establishing the required public hearings and he or

his designate together with his staff and advisors would have the independent responsibility for reviewing and evaluating the Impact Statement and all comments (governmental and public), publishing their conclusions and reporting and advising the Policy and Priorities Board and the Provincial Cabinet on appropriate action. This method has the advantage of making use of the existing government framework.

- (ii) Alternatively, a broad-based energy regulatory board could be established by law to consider all aspects of energy use in Ontario and with the authority to approve and reject proposals. Consideration of environmental issues through the impact statements would only be one aspect of the board's activities. Other activities could include, reserve forecasting, resource developping, price structure, etc. It could be made up by appointment of specialists in many fields (engineering, economics, law, ecology, etc.) and representatives of the public. The board would (1) utilize experts in appropriate government agencies to assist in the evaluation of the Environmental Impact Statements or other material, (2) hold hearings on all aspects of energy use, and (3) request additional studies if necessary. Positive decisions by the board to proceed would be referred to the Cabinet so that additional factors could be weighed before a final decision is reached. A negative decision

of the board not to proceed for technical reasons would require no further action. This approach has the advantage that it considers environmental problems in a broader context and may fit into a broader policy recommendation.

3. Recommendations on Energy Resource Development

3.1 Control of Radioactive Releases

It is recommended that future extraction of uranium ores take place with adequate environmental protection. The following steps are necessary for the protection of environmental quality in the area necessary for the protection of environmental quality in the mining areas:

- (i) Stabilization and maintenance of all abandoned tailings areas to secure, in perpetuity, their containment including isolation and cover, and erosion control. Collection and treatment of seepage and runoff should be provided by the mining companies or their successors responsible for the disposal sites. Legislation dealing with stabilization of tailings areas by vegetation or other methods should be extended to include abandoned areas and, as required, treatment of seepage and runoff.
- (ii) Mining companies pursue the use of improved process and waste treatment techniques such as sulfide removal. Priority be given to the control of pH and toxic compounds such as heavy metals and ammonia.

- (iii) Prohibition of the use of lake basins for containment of tailings at new mining locations.
- (iv) Further studies are needed to examine the total human intake of radioactivity through air, food and water in those areas where waters containing significant quantities of radio-nuclides are used for domestic water supply. It is expected that the radiation dose resulting from short-term use of these supplies does not present a significant hazard to health; however, it would be advisable to consider alternate supplies since any unnecessary exposure to radioactivity should be avoided.

In view of the growing consumption of energy and the existence of other environmental forces directing us toward the installation of ever-increasing nuclear power capacity, it is recommended that the following policies be adopted.

- (a) Radioactivity in the aquatic and atmospheric environments attributable to controlled releases from all operations be kept to the lowest practicable level.
- (b) All release levels be carefully reviewed periodically and revised so that the build-up of long-lived radioactivity in the environment not unwittingly become a legacy for future generations.
- (c) The nuclear industry and nuclear power plants not be allowed to release more radioactive material than is currently the practice. Moreover, the present legal maximum release limits be immediately reduced to the lowest practicable levels.

- (d) From an environmental viewpoint the use of breeder reactors be discouraged until their environmental consequences are well-defined and judged tolerable. Further, the environmental impact of fuel-reprocessing plants and uranium-enrichment plants be carefully evaluated and very low radioactive release levels established before they are allowed to operate in Ontario.
- (e) The total amount of radioactivity in the sediments, water and biota of the Great Lakes not be allowed to increase by the discharge from future nuclear power-plants.
- (f) Contingency plans to cover mass evacuation from nearby populated areas in the event of (a) leakage from a nearby nuclear generating station or (b) from a heavy water plant, be periodically reviewed as population trends change over the next two decades.

### 3.2 Development of Onakawana Lignite Deposits

The Northern Ontario environment is believed to be fragile with respect to environmental stress. If the Onakawana lignite deposits are developed, it is recommended that this development be strictly controlled to ensure a minimum environmental impact. In addition, Environmental Impact Statements are recommended for all energy developments such as this. Such development should be preceded by complete ecological and environmental studies.

The gasification of this lignite would ensure an environmentally desirable fuel for Ontario. Consequently, it is further recom-

mended that an on site lignite gasification plant be considered in the development of this resource, and that the research and development work needed to promote this development concept be undertaken.

4. Processing of Fuels

4.1 Crude Oil

- (i) To minimize the adverse effects which would almost certainly result from a major spill of fuel oil or other hazardous materials, it is recommended that contingency planning activities receive a high priority within the Government and that an effective response capability be developed.
- (ii) Expansion of refinery operations may potentially increase discharge of pollutants into waterways. It is recommended that waste discharges be reduced and be in strict compliance with the maximal permissible amounts of individual pollutants such as oils and phenols.
- (iii) Continuation and intensification of the study of the origin of photochemical oxidants in effected areas of Ontario is recommended. An understanding of all factors involved is necessary in order to establish an environmental limit and meaningful hydrocarbon emission and ambient air-quality standards.
- (iv) Process upsets which may result in excessive carbon monoxide and particulate emission from catalytic cracking units should be discouraged by provision of heavy

finer if such upsets occur relatively frequently.

- (v) Similarly, emission of malodorous compounds should be discouraged by provision of heavy fines for frequent violators.

## 5. Recommendations Pertaining to Utilization of Fuels and Energy

### 5.1 Electrical Power Generation

Ontario Hydro is interacting more strongly with Provincial Government Ministries on environmental matters. Since the organization is an agency of the Ontario Government and the government's stated policy is to provide adequate energy supplies and to achieve a satisfactory environmental quality, electrical power production should implement both aspects of this policy.

- (i) Increased electrical power generation will result in more widespread environmental degradation in the future. Recognizing and accounting for external diseconomies is an important first step towards improved environmental quality, and aid in resolving the basic conflict between power generation and environmental quality.

- (ii) It is recommended that advertising, marketing policies and rate structures be designed to encourage conservation of electricity as long as the production of electrical power has a significant impact on the environment as it does now. A pricing policy for electrical power should also encourage the use of pollution abatement equipment by industry and municipalities thus shifting consumer preference away from products which use electricity inefficiently and therefore have a larger impact on environmental quality.
- (iii) Electrical power production achievement should be judged not only on how efficiently and economically power is produced, but also on minimizing the overall impact on the environment.

5.1.2 Expansion of the Environmental Program

Ontario Hydro has an internal research and development program in pollution control, supports work in other organizations and employs environmental consultants. Their research and development work related to environmental matters is about 10 to 15 percent of their total research and development program.

It is recommended that an expanded research and development program be carried out in those problem areas which are unique to Ontario by virtue of its geographical location and climate and which are attendant to power production by large energy generation

centres being planned. Some areas requiring research are (a) the effects of large onshore discharges of cooling water on lake currents and ecosystems, (b) analytical and experimental investigation of the potential of icing and fogging from cooling towers and lagoons and investigations of the aerodynamic interference of the cooling tower on its discharge plume, (c) undertaking of conceptual studies of the beneficial uses of waste heat.

The Commission already has research and development work underway in pollution control, but the problems are of sufficient importance that their existing program should be increased. Several specific suggestions are made in the body of the report. An expanded investigation of the removal of sulfur dioxide and oxides of nitrogen from flue gases, the study of fluidized-bed combustors, the development of new transmission methods or underground cables are noteworthy among these. Because the Commission cannot be expected to work extensively toward the solution of all environmental problems associated with electrical power production, the regulatory agencies could aid in establishing priorities so that necessary environmental quality goals may be achieved. Further, Ontario cannot afford to await for these problems to be solved elsewhere.

#### 5.1.3 Generation Plants with Minimal Environmental Impact

Each type of generating plant produces a very different kind of impact on the environment. As a result, it is difficult to

make meaningful comparison. Nevertheless, it is believed that a nuclear plant using the CANDU system will produce a lower overall environmental impact than other contemporary power generation systems provided the following steps are taken:

- (a) Uranium mining practices recommended previously are followed.
- (b) The release limits of radioactive emissions into the water and air are reduced to the lowest practicable levels.
- (c) Methods to dispose of radioactive waste from an expanded nuclear power-generation industry in the next two decades are to be carefully investigated now.

The following guidelines are recommended:

- (a) To improve air quality - the installation of future coal- or oil-fired plants be avoided in the southern portion of the Toronto Centered Region and in any case large fossil-fuel power generation centres of 4000 MW and greater not be spaced less than 30 miles apart in other regions.
- (b) To improve air quality - natural gas be reserved for use where other emission control measures are not practical. Its use is not recommended for future generation stations where other control methods can be employed.
- (c) To improve air quality - Ontario should strive to achieve a Canadian policy of retaining environmentally desirable natural gas for Canadian use.

- (d) To improve water quality - once-through cooling not be allowed for future plants sited on the Western Basin of Lake Erie.
- (e) To maintain water quality - in other areas where harmful effects can be predicted, alternative cooling facilities, which will not seriously impact the aquatic environment, should be employed. In those instances where potential harmful effects may exist, but cannot be clearly predicted, power plants should be initially designed so that alternate cooling facilities can be added at such time as evidence indicates significant adverse effects. Cooling water discharges should not alter local existing circulation patterns such that other water uses are seriously depreciated, or spawning and fishing grounds are affected.

If future development of hydroelectric plants is undertaken the following is recommended:

- (a) Long-term studies are necessary to investigate future water needs and the potential consequence of major diversions.
- (b) An Environmental Impact Statement be required for the development of future hydroelectric power developments. It may include or specify the completion of an ecological and socio-economic study of the region.
- (c) Land should be purchased and managed for public access, boat-launching, shore fishing and other facilities within the reservoir levels should be maintained for optimal recreational benefits.

- (d) Migrations and spawning and culture of fish should be maintained. When spawning habitat is lost, stocking and spawning channels be provided.

5.2 Recommendations Pertaining to Transportation

5.2.1 Automotive

Legislation governing air pollution control devices on new vehicles is established by the Federal government. The technology needed to satisfy the legislation is primarily being developed in the United States. Ontario can take some steps in this important area:

1. (a) Automotive emissions should be reduced to a level corresponding to the 1973 federal emission standards. If there is any question of not implementing 1976 standards in Ontario, a complete review covering all environmental, social, and economic factors should be undertaken before a decision is made. The 1976 standards will require expensive abatement devices to control emission of the nitrogen oxides, an ingredient in photochemical smog. The recommended review should consider;
  - (i) The need of the abatement devices in Ontario.
  - (ii) A detailed investigation of the potential for photochemical smog formation in Ontario cities
  - (iii) The economic impact on the Province should be compared with the environmental benefits

derived.

- (iv) The possibility of restricted international vehicle travel between countries with different auto emission standards.
  - (v) The problems introduced by different automotive fuel standards between Canada and the U.S. relating to lead content and octane rating.
- (b) Regulations restricting automotive emissions should also provide that emission standards are to be met during the normal use of the vehicle. Effectively-administered emission control tests should be required at regular intervals of about one year.
- (c) Adoption of lower lead standards in ambient air is recommended and a reduction of the maximum permissible level of TEL in gasoline should be considered. Alternatively, regulatory price policies could be introduced in order to provide an incentive for consumers to buy unleaded or low-lead instead of leaded gasoline.
- (d) Legislation against unnecessary idling of all motor vehicles in urban areas should be introduced and enforced.

2. The conversion of urban vehicles to natural gas or propane should be encouraged by tax incentives and other methods. The conversion of some provincial vehicles should be continued and fleet operation experience thus obtained. This recommendation is contingent upon the foresight of the

Advisory Committee on Energy in regard to the long-range availability of such fuels considering the other uses of natural gas recommended herein.

3. Every practical effort should be made to eliminate unnecessary use and losses of deicing salt. Direct disposal of snow on lakes or rivers should be eliminated wherever possible and suitable land disposal sites with facilities for trapping the suspended solid, oil and debris should be provided.
4. Effective noise control measures must include control of noise emissions at the source. Regulations restricting noise emission for new motor vehicles to increasingly lower future levels should be introduced and should specify that noise standards are to be met during the normal use of the vehicle. Replacement equipment which emits higher noise than the original equipment should be banned from sale. Adequate provisions should be made to enforce the noise emission standards during the operation of vehicles in order to protect the public from persistent offenders.
5. Environmental Impact Statements are recommended in the planning of new freeways and major highways. They should at the minimum evaluate the problems of noise, air pollution and effective land use.

#### 5.2.2 Mass Transportation

Clearly the best long-term solution to the problem of automotive pollution is to reduce the use of automobiles in urban areas.

This may be achieved by providing fast, economical and comfortable mass-transportation. Consequently, it is strongly recommended that efforts in providing mass transportation systems in heavily populated areas be intensified. The Province could lead the way in North America in this field. The following steps are recommended:

- (i) Long-term development of cheap, fast and efficient mass transportation systems. Expansion of existing systems and planning and provision of additional mass transportation systems for large urban areas.
- (ii) Promotion of public transit over urban automobile travel by provision of increased comfort and reliability. Provision of adequate and free terminal parking and minimal fare rates. Cars in downtown areas of large cities be further discouraged. Possible methods include the introduction of regulatory policies to increase parking rates for day-long downtown parking and the restriction of on-street parking.
- (iii) The government via the Ministry of Transportation and Communications increase substantially research and development of new transportation systems. The potential of new innovative mass transportation methods be assessed.
- (iv) Large developments in cores of urban areas be planned

in conjunction with the development of mass transit systems which are capable of handling the increased passenger traffic. Large new urban developments should require an assessment of their effect on the environment and commuter traffic which should be of major consideration for their approval. Environmental Impact Statements are recommended for such projects.

5.2.3 Aviation and Airports

- (i) Aircraft and airports do not present serious air- or water pollution problems. However, smoke, odor and hydrocarbon emissions from jet aircraft engines should be reduced by an early implementation of emission control by available technology.
- (ii) Noise emission of jet aircraft while ascending or descending be reduced within the limits of acceptable safety to airplane operation. Flight paths of ascending or descending aircraft should avoid densely populated areas. The use of land surrounding major airports be planned in such a way that the effect of aircraft noise on the population is minimized.
- (iii) New airport sites should require the submission of an Environmental Impact Statements which would be of major consideration for their approval. Planning of new airports should be in due consideration of the potential impact on the environment. The size and capacity of air-

ports should be in accordance with an acceptable impact on air quality and noise level.

5.3 Recommendations Pertaining to Residential and Commercial

Impact

- (i) It is recommended that stricter codes for new residential and commercial buildings be developed and that these codes be implemented as soon as possible. Such codes would serve to conserve energy and would assist in reducing the impact on air quality of these area-wide sources.
- (ii) It is recommended that the use of gas be reserved primarily for residential and commercial uses and that electrical heating systems be discouraged for the time being. The use of low-sulfur fuel appears to be the best strategy for controlling sulfur-dioxide emissions from these numerous sources. From an environmental standpoints, (1) residential and commercial consumers in urban areas, (2) certain industrial users and (3) critical air-pollution abatement application should have priority for natural gas. It is also recommended that sulfur restrictions in fuels be implemented where SO<sub>2</sub> emissions from residential or commercial buildings constitute a problem.
- (iii) It is recommended that more efficient types of combustion systems of lower pollution potential be developed for residential and commercial buildings and that future

developments of residential and commercial heating systems consider ways of reducing emissions of the nitrogen oxides. Government could assist in obtaining these objectives by grants or product development loans.

- (iv) Operational checks and adjustments of all residential and commercial furnaces on a regular basis be made mandatory.
- (v) It is further recommended that the feasibility of providing total energy systems for large residential and commercial developments be considered. Also, it is recommended that research be undertaken into methods of conserving energy and increasing the efficiency of energy use (both fossil fuel and electric) in residences and commercial buildings and that an active program be undertaken to eliminate unnecessary consumption.

#### 5.4

##### Recommendations Pertaining to Energy Use by Industry

- (i) It is recommended that a policy of requiring Environmental Impact Statements for future applications of fossil-fuel and nuclear energy resources by industry be established. This recommendation is made specifically for energy applications because this is the area of responsibility of the Advisory Committee on Energy.

- (ii) It is recommended that the use of natural gas or low-sulfur coal by industrial consumers be controlled so that adequate supplies will be maintained in the future where it is necessary for the manufacturing process or where no other air-pollution abatement methods is possible. Similarly, as it becomes scarcer, the use of low-sulfur coal should be restricted to those operations where it is essential.
- (iii) It is recommended that incentives be provided to industry to complete the research and development work of coal-gasification and promote development of large scale facilities in Ontario which would have minimal environmental impact. In this manner, it may be possible to develop the Onakawana lignite as an environmentally clean energy resource for all of Ontario.
- (iv) Because many products require much less energy if recycled than if produced from virgin materials, it is recommended that the use of recycled materials in the production process by regulatory tax policies, development grants or other means at its disposal be encouraged. Where incentives are in federal jurisdiction, the Province should press the federal government for similar policies.

Recommendations Pertaining to Recreation Energy Uses

The use of energy in recreational vehicles per se causes modest environmental problems. However, the use of the vehicles themselves may cause serious long-term effects. In view of these factors the following recommendations for further action are made:

- (i) Legislation is needed to provide for the limitation of the size of motorized vehicles, and, in particular, outboard motors. The regulations under such legislation should provide for the limitation of the size of motors in accordance with the size of the waters designated for such control.
- (ii) The use of motorized recreational vehicles, such as snowmobiles should be limited to designated areas. Legislation should provide for a method which will permit the easy identification of snowmobiles and other vehicles.
- (iii) Areas of land and water needed for the survival of plants, animals, and other life, which are rare or in jeopardy, should be described and should be designated under existing or new legislation as areas not open to use by motorized recreational vehicles.
- (iv) Noise regulations governing the operation of motor-driven recreational vehicles of all kinds which are badly needed be promulgated under the Environmental Protection Act.

- (v) Research and development to devise engines for motorized recreational vehicles which do not introduce fuel into water be given a high priority.

6. Recommendations Pertaining to Land Use Planning

- (i) It is recommended that (where consistent with reliability of service) the concept of "the energy-transit corridor", grouping transmission lines, pipelines, transportation lines together, thereby reducing the amount of land needed for utility easements be promoted. By having multi-utility easements planned in such a manner, the corridors can offer additional and needed recreational areas and also can provide rapid-transit rights-of-way in urban areas.

The following recommendations are made with respect to such corridors:

- (a) Investigate the use of transmission line rights-of-way to serve also for a rapid surface mass-transportation systems with a low air-and noise-pollution potential.
- (b) Intensify studies on multiple use and utilize rights-of-way for recreational purposes. Accelerate studies on how to obtain additional multiple use values from transmission lines by establishing and maintaining low cover for wildlife habitat and food.

- (c) Develop techniques directed toward the future replacement of major transmission lines with underground cables in some areas. Where feasible, replace lines over water by submarine cables.
  - (d) Intensify studies to maintain or improve the aesthetic values of freeway, airports, power generating installations and transmission lines by sculpturing, visual screening, etc.
  - (e) Locate large energy centers to avoid conflict with designated wilderness areas, "wild" rivers, valuable woodland and special areas of ecological interest and/or historic significance.
- (ii) It is recommended that certain waste disposal problems attendant to energy use be more carefully evaluated:
- (a) Investigations should be initiated to determine the overall impact of the disposal of radioactive wastes as well as chemical compounds formed as a result of flue gas cleaning methods.
  - (b) A study should be undertaken to determine if Ontario may have any long-range problem in the disposal of nuclear wastes and whether the present division of responsibility for control of the disposal of such waste with the Federal Government will be adequate in the future.

7. Recommendations Pertaining to Long-Range Implications of  
Energy Use

Various agencies should assume the responsibility for long-range studies of the consequences of exponential growth, energy consumption and electrical power generation. The conflict between our way-of-life and the environment is no sharper than in the consumption of energy resources. These long-range environmental trends should be forecast as a natural extension of the activities of the Advisory Committee on Energy.

Because energy consumption cannot continue indefinitely in a finite world, it is recommended that a permanent body of experts and leaders from a broad cross-section of society be appointed to study and make recommendations concerning the implications, timing and mechanisms involved in the limits of growth. Although these limits may not be reached for many decades, it is not too early to predict the long-term trends and consequences of growth and to decide the means to optimize growth for the benefits of society.

### III. ENVIRONMENTAL IMPLICATIONS OF ENERGY USE

#### 1. Some of the Problems

This section discusses the known and expected environmental degradation caused by energy use on the air, water, and land as summarized in Table 1. In most cases, degradation occurs in more than one facet of the environment. Corrective measures to improve one environmental problem may result in further degradation of another environmental quality. Therefore, it is necessary to consider all environmental impacts and closely co-ordinate control measures to obtain an acceptable total environment. For the purposes of this study, an energy consumption forecast has been prepared (Figure 1). It is based on an exponential growth for the next twenty years. Clearly, any society cannot continue to expand in this manner over a period of time.

#### 1.1 Effects on Air

The impact of processing and using energy, is the dominant factor affecting the quality of the air. Many emitted contaminants pollute the atmosphere, however, five major pollutants comprise by far the major load, i.e. particulate matter, sulfur dioxide, carbon monoxide, oxides of nitrogen and hydrocarbons.<sup>(1)</sup> These contaminants are most prevalent in urban centers.

An example of the atmospheric degradation resulting from the utilization of energy in an urban area is shown by the inventory of air pollutants in the Toronto area.<sup>(2)</sup> Table 11 illustrates that about 90 percent of the air pollutants in Toronto are a

TABLE I

## ENVIRONMENTAL IMPACT OF ENERGY USE

		Energy Sources				
		Coal	Oil	Natural Gas	Nuclear	Hydro
EFFECT ON AIR	Obtaining					
	Processing, etc.	Dusting Coke Emissions	Refinery Emissions	Handling Emissions	Radioactive Dusts	
	Utilizing	Particulate SO <sub>2</sub> NO <sub>x</sub> Heavy Metals	CO NO <sub>x</sub> CxHy SO <sub>2</sub> Heavy Metals	NO <sub>x</sub> CxHy	Accidental Spills Regular Losses Cooling Tower Evaporation H <sub>2</sub> S Emission	
EFFECT ON WATER	Obtaining	Acid Drainage	Potential Spills		Acid Drainage	Altering Water Shed, Natural Flow
	Processing, etc.		Accidental Spills		Dissolved Salts Radioactive Waste Disposal	
	Utilizing	Increased Local Temperatures Dissolved Salts Large Cooling Water Flow	Increased Local Temperatures Large Cooling Water Flow	Increased Local Temperatures Large Cooling Water Flow	Increased Local Temperatures Waste Disposal Large Cooling Water Flow	Fluctuating Stream Flows, Lower Flow Rates
EFFECT ON LAND	Obtaining	Disturbing Land	Pipeline	Pipeline	Disturbing Land	Disturbing Land
	Processing, etc.	Solid Waste			Radioactive Waste Disposal	
	Utilizing	Solid Waste Disposal	Waste Disposal		Waste Disposal	

Figure 1

Energy Consumption in Ontario

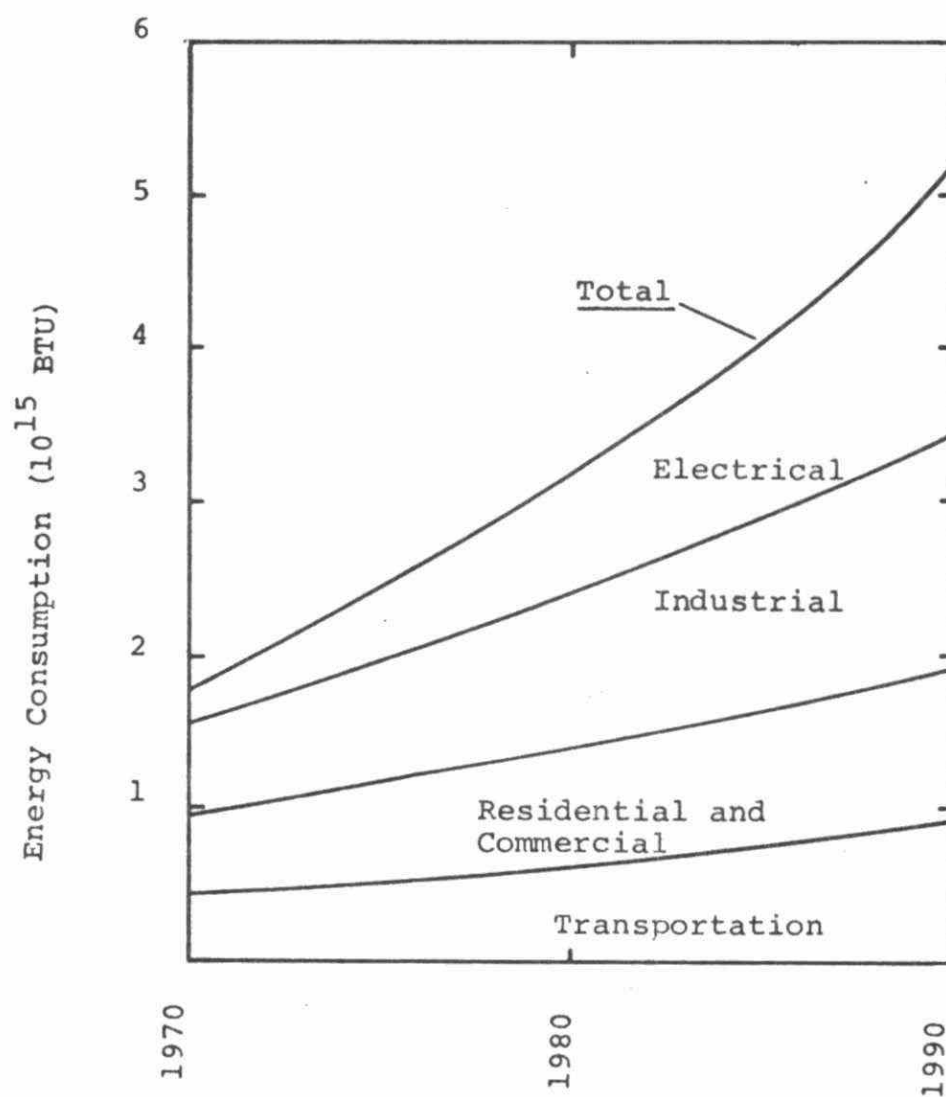


TABLE II  
EMISSION SUMMARY BY POLLUTANT FOR METROPOLITAN TORONTO  
(PERIOD APRIL 1, 1971 to APRIL 1, 1972)

MILLIONS OF LBS. EMITTED PER YEAR; IN BRACKETS: PERCENTAGE OF TOTAL

SOURCE TYPE	SO <sub>2</sub>	PARTICULATE	NO <sub>x</sub>	CO	HC
R.L. HEARN G.S.	34.64( 7.33)	0.62( 1.23)	26.44(13.14)	0.29( 0.03)	0.12( 0.06)
LAKEVIEW G.S.	348.28(73.74)	5.94(11.82)	80.19(39.87)	2.00( 0.23)	0.81( 0.43)
MUNCIPAL INCINERATORS	0.55( 0.11)	12.13(24.15)	1.35( 0.67)	3.28( 0.38)	0.16( 0.08)
INDUSRRIAL SOURCES	23.25( 4.92)	12.08(24.05)	17.64( 8.77)	4.89( 0.57)	43.64(23.50)
AUTOS	3.49( 0.73)	4.65( 9.25)	43.65(21.70)	827.36(97.53)	126.42(68.09)
RAILROADS	0.43( 0.09)	1.08( 2.15)	2.19( 1.08)	0.59( 0.06)	1.33( 0.71)
SHIPPING	0.90( 0.19)	0.41( 0.81)	0.66( 0.32)	0.24( 0.02)	0.32( 0.17)
AIRCRAFT	0.24( 0.05)	1.18( 2.34)	1.14( 0.56)	2.21( 0.26)	10.61( 5.71)
HEATING - RESIDENTIAL	19.82( 4.19)	2.49( 4.95)	5.91( 2.93)	0.52( 0.06)	0.76( 0.40)
HEATING - APARTMENTS	10.73( 2.27)	3.99( 7.94)	5.68( 2.82)	3.88( 0.45)	0.84( 0.45)
HEATING - SCHOOLS & UNIV.	8.29( 1.75)	0.83( 1.65)	2.69( 1.33)	0.29( 0.03)	0.11( 0.05)
HEATING-PUBL.&COM.BLDGS	14.40( 3.04)	2.83( 5.63)	10.77( 5.35)	0.74( 0.08)	0.34( 0.18)
SMALL INDUSTRIES	7.19( 1.52)	0.83( 1.65)	2.54( 1.26)	0.23( 0.02)	0.10( 0.05)
INCINERATION: APART MENTS, SCHOOLS, SMALL INDUSTRIAL, PUBL. AND COMMERCIAL BUILDINGS	0.07( 0.01)	1.16( 2.30)	0.26( 0.12)	1.76( 0.20)	0.11( 0.05)
TOTAL	472.29	50.22	201.08	848.26	185.66

direct result of energy utilization in transportation, electrical power generation and heating. The automobile is the greatest single source accounting for 56 percent of the total pollutants (mainly carbon monoxide). The two electrical power generation stations generated an additional 28 percent of the total pollutants (mainly sulfur dioxide). Detailed data of this type are not available for Ontario as a whole; however, the trends are expected to be somewhat similar to Toronto's for other urban areas. Improvements made in urban areas by the use of higher stacks result in increased ambient pollutant concentrations in the rural areas. The formation of smog is another urban air pollution problem distinct from the one outlined above. <sup>(3)</sup> Under the influence of sunlight, the oxides of nitrogen and gaseous hydrocarbons interact to form a complex variety of secondary pollutants called photochemical oxidants. These compounds, together with other liquid and solid particulates in the air, are commonly known as smog. Automobiles and to a lesser extent electrical power stations are the prime contributors to photochemical smog. Because sunshine and still atmospheric conditions are needed to provide the energy and time for these reactions, it is apparent why the problem has arisen in Los Angeles, but is, at least as present, not severe in Ontario.

## 1.2

### Effects on Water

The obtaining of energy by mining can cause acide drainage or radioactivity problems in the adjacent watercourses. These substances deny portions of the downstream watercourse for other

uses. The disposal of radioactive wastes from mining has caused significant water degradation.<sup>(4)</sup> The utilizing of energy has both a physical and chemical effect. Large volumes of cooling water discharge required for fossil-fired and nuclear generating stations change both the local temperature and natural movement pattern at the discharge. Chemical by-products are also introduced into the water stream.<sup>(5)</sup> The physical effects of once-through cooling systems can be both beneficial and detrimental.

There has been a large amount of discussion about discharging the waste heat from electrical power generation stations into the water. The main concern has arisen in the United States where large power plants have been located on relatively small and warm lakes and rivers.<sup>(6)</sup> It is well-known that heat accelerates the biological decay process in water and reduces the capacity of the water to retain dissolved oxygen and other gases. Thus, heated water can assimilate less biological waste. On the other hand the growth of aquatic plants including algae is accelerated. Also, increased water temperatures can interfere with or disrupt the reproductive cycles of fish and migration patterns. The short and long-term effects on the fishery, biological activity and the chemical and physical characteristics of all aquatic areas are not completely known at this time.

Normal sanitary and industrial wastes discharged into the water must conform to existing provincial requirements. Regulations

regarding the release of radioactivity are presently under review by the Atomic Energy Control Board in co-operation with a number of Federal and Provincial agencies and revised water-quality objectives for radioactivity will likely be promulgated within one year. Specialized releases, like  $H_2S$  emanating from heavy-water plants, must also conform to existing provincial requirements.

### 1.3

#### Effects on Land

Mining of energy resources has historical implications of affecting the aesthetics and future land utilization. The increasing acidity of waters in mining areas are in part due to poor land-use practices. <sup>(7)</sup> While the major known energy resources within Ontario are restricted to lignite and uranium, the development of these resources must be regulated to ensure that the land environment is protected.

Hydroelectric power generation has direct effects on the use of land caused by varying the natural flow of streams and developing artificial impounding areas. Presently, most of the hydraulic potential for power generation in Ontario has already been developed and it is expected that future problems will be associated with flow regulations initiated to maximize power production.

Transportation of energy creates aesthetic problems associated with electrical transmission lines and occupies large land areas. The problem of an accidental spill from energy conveying systems on land or water transportation and pipelines is ever present and intensifies with population

growth. The application of herbicides and defoliants to control vegetation growth on transmission line and pipeline rights-of-way may also give rise to a variety of problems. Many of these compounds are very persistent and tend to be concentrated in living organisms. The ultimate effect of these substances is not well documented.

#### 1.4 Causes of Problems

Profit seekers are often blamed for the degradation of our environment. However, there are more fundamental causes. A large majority of people have been willing to consume vast amounts of resources and energy, failing to understand that the modern way-of-life is basically responsible for the deterioration of our water, air and land resources. The prosperity of a society is directly related to its ability to compete economically with others. Consequently, it is economically difficult for one group, one industry, one province or one country to justify accepting its environmental responsibility, if its neighbours or competitors do not. A multi-lateral approach is needed to effectively solve environmental problems. Its absence frequently only effects a partial solution. Unfortunately, this reasoning is more frequently becoming an excuse for no action.

#### 1.5 Economic Incentives to Pollute

Our present pricing system fails to take into account the damage a polluter inflicts on others. Air, water, and land are generally regarded as "free goods". As a result, this system produces very real, but hidden, external social costs which are

imposed on consumers and non-consumer alike. Although there is considerable controversy as to the actual hidden costs of pollution, the Environmental Protection Agency (EPA) estimates that the annual toll of air pollution in the U.S. on health, vegetation, materials and property values exceed \$80 per person per year.<sup>(8)</sup> A somewhat lower, but similar, cost exists in Ontario. The cost of water pollution damage is less well documented. Clearly, there are increasing present-day losses in contaminated fish and potential future economic losses due to increased water-treatment costs. Costs of lost amenities and recreational opportunities are still more intangible, but none the less they are real economic costs. A price and/or tax structure that took environmental degradation into account could shift consumer preferences and perhaps discourage the purchase of goods which are manufactured by pollution producing facilities.

#### 1.6

##### Population Growth

Population and consumption are the key to the environmental problem. Population growth was of no concern and encouraged in most parts of the world until a few decades ago. It has been somewhat difficult to recognize the potential problem in a country as sparsely populated as Canada, but when the weak life-support systems of much of our area are considered, there is greater cause for concern. Mushrooming population growth does not necessarily mean more polluted air and water, but it is more difficult to achieve and maintain environmental quality with the pressure of population growth in a given area. It is

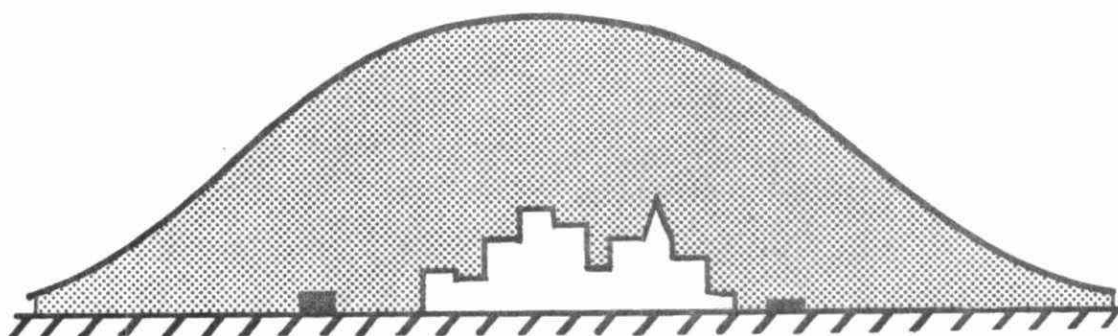
interesting to note that 20 percent of the world's population (North America, Europe, and Japan) is considered responsible for about 90 percent of the earth's environmental damage.<sup>(9)</sup> An average North America is reported to cause about the same impact on the environment as 200 people in India or 50 in South America. The environmental impact of the population growth in Ontario will be increasingly felt.

#### 1.7 Increased Urbanization

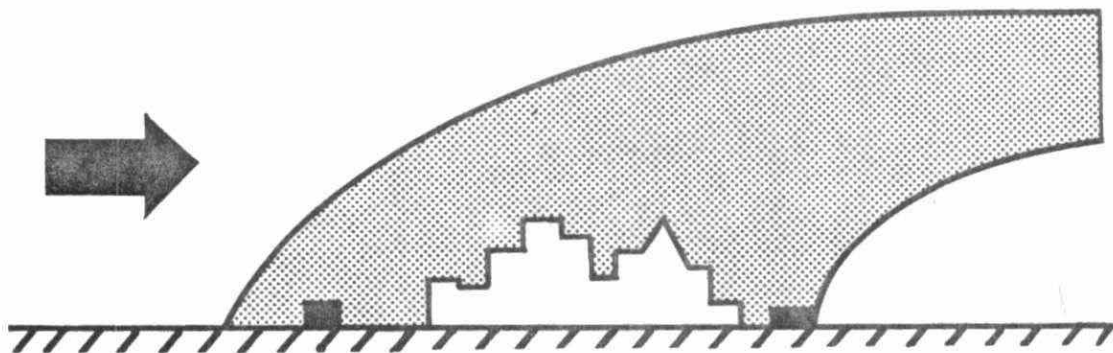
Our environment provides natural mechanisms to clean and restore itself. Some of these processes we understand, but most of them are still a mystery.<sup>(10)</sup> Concentrations of people in urban areas intensify the pollution problem, yet urbanization continues to grow. For example, population forecasts for Ontario<sup>(11)</sup> indicate that the Toronto-centered region will grow faster than the remainder of the Province by the end of the century. Statistics have shown that in the U.S. increased pollution is directly related to increased population; similar data is not available for Ontario due to the limited number of cities.

The pollution domes of our cities as illustrated in Figure 2 are becoming visible. This dome, due to urbanization, changes the climate of a city as outlined in Table III. Many may feel that higher temperatures and fewer heating degree days, particularly in the north, are an advantage, but few people enjoy less sunshine and increased cloudiness, fog and rainfall which also occur.

FIGURE 2



The urban dome



The urban thermal and pollution plume occurring when a regional wind is blowing.

TABLE III

Average Changes in Climatic Elements Caused by Urbanization

<u>ELEMENT</u>	<u>COMPARISON WITH RURAL ENVIRONMENT</u>
Contaminants:	
condensation nuclei and particles	10 times more
gaseous admixtures	5 to 25 times more
Cloudiness:	
cover	5 to 10 percent more
fog--winter	100 percent more
fog--summer	30 percent more
Precipitation:	
totals	5 to 10 percent more
days with less than 5 mm	10 percent more
snowfall	5 percent more
Relative humidity:	
winter	2 percent less
summer	8 percent less
Radiation:	
global	15 to 20 percent less
ultraviolet--winter	30 percent less
ultraviolet--summer	5 percent less
sunshine duration	5 to 15 percent less
Temperature:	
annual mean	0.5° to 1.0°C more
winter minima (average)	1° to 2°C more
heating degree days	10 percent less
Wind speed:	
annual mean	20 to 30 percent less
extreme gusts	10 to 20 percent less
calms	5 to 20 percent more

(from reference 12)

As urbanization spreads, we gradually alter our climate over a wider area and continue to magnify our pollution problems. Controlling or placing a ceiling on urban size and maintaining rural areas between urban centers will be necessary to maintain a good air quality in the future.

1.8 Other Factors

Our very way of life in North America contributes to a large degree to our mounting environmental problems. Our affluence places a strong emphasis on consumer goods. Advertising pushes us toward over-consumption and develops a throwaway psychology as the norm. Natural things are steadily displaced by synthetic products by our rapidly developing but uncontrolled technology. The consequences of some of these changes are seen as to negatively affect our overall quality of life already now.

2 Impact of Energy Resource Development

Inasmuch as Ontario is an "industry rich and energy poor" Province and imports most of its energy resources, some of the environmental damage attendant to its energy consumption will not occur in Ontario. The Province is fortunate in this sense. However, it must be realized that the present price of some of Ontario's energy purchases does not reflect the true cost of the resource. It is apparent that the cost of such fuels will rise in the future as the government and people in these areas become more environmentally aware and costly pollution-abatement measures are undertaken.

An example of this trend may be found in the Appalachia coal-mining area in the U.S. The coal mining industry there spent

6.1% of its capital investment in 1969 on pollution control measures. This figure increased to about 8.5% in 1970.<sup>(8)</sup> With enactment of the pending Mined Area Protection Act<sup>(13)</sup> in the U.S., pollution-abatement costs and hence the cost of coal imported from that country, would be expected to continue to rise. This trend will exist also for fuels imported from other Canadian provinces. Fuels imported from the undeveloped areas of the world, however, particularly the Southern Hemisphere, would likely be subject to lower pollution-induced price increases over the longest period of time.

The following summary only applies to the impact on Ontario's environment of obtaining fuel.

## 2.1 Onakawana Lignite Deposits

At the present time all of the coal used in Ontario is imported and hence produces no pollution problems here. However, the Onakawana lignite deposits in Northern Ontario are being considered as an energy source.<sup>(14)</sup> While the available technical information concerning the Onakawana lignite deposit is sparse, fairly accurate generalizations can be made with regard to the probable environmental impact of mining the deposit.

### 2.11 Water Pollution

Since the Onakawana lignite deposit is overlain by an average of 65 feet of silt, sand and boulder clay, it appears unlikely that a conventional underground mining plan could be followed with any degree of safety. Consequently, a surface method

of mining which would minimize the impact on the environment could be followed. A specific method is suggested in a brief analysis of the problem contained in reference 15.

The overburden heaps in the coal-producing Appalachia region of the U.S.A. generate acid mine drainage problems. However, the overburden of the Onakawana deposit will not generate acid mine drainage, because;

- (1) The material covering the Onakawana deposit consists of sand, gravel, limestone, shale and clay, which was deposited in the area as a result of glaciation. Iron sulfides, which produce acids, do not occur to any significant extent.
- (2) The overburden is quite alkaline in nature and will, in all probability, neutralize any acid that might be generated.

The Onakawana River, however, runs directly across the extent of the deposit, as it is currently known. Consequently, if the water quality of the Onakawana River and other streams in that drainage basin are not be affected by mining operations, considerable quantities of lignite adjacent to the rivers will have to remain untouched. Alternatively, the river itself might be diverted (into the Abitibi River) before it reaches the mining area. However, detailed ecological studies of the area should be made prior to selecting this approach.

Publications from Australia indicate that lignite mining faces are continually subjected to a water spray in order to avoid spontaneous combustion. If water sprays are required at the Onakawana property, turbid runoff could occur. Due to the nature of the operations, however, runoff problems of major proportions are unlikely to develop.

Finally, it is suggested that the deposit should not be developed unless the rehabilitation procedures required under the terms of Section 168 (1) of the Mining Act closely follow mining operations. The natural surface of the landscape would be entirely destroyed but spoil (waste) piles can be recontoured and revegetated as mining progresses. Also, the recontoured waste piles should be revegetated with species native to the area. In this regard, revegetation and proper contouring will be difficult if not impossible during the long winter months.

In summary, it is clear that a detailed study of the environmental problems is needed before the development of the area begins. However, preliminary studies indicate that acid mine drainage should not be a problem. Obviously, processes such as mining under wet conditions and coal washing could give rise to turbid effluents in the streams of the area. Land rehabilitation should and could be undertaken as mining proceeds.

#### 2.1.2 Air Pollution

The mining of the Onakawana lignite should not cause any major air pollution problems.

### 2.1.3 Impact on Land

Past experience has shown in a variety of ways, that nature as a whole is in a state of dynamic equilibrium. It may be expected that mining and industrial activities in the James Bay area will affect this equilibrium.<sup>(16)</sup> Environmental problems, which could occur, may be intensified when the environment is imperfectly understood, and especially when it constitutes special problems of temperature and drainage as does the northern regions in Ontario. The capacity of northern ecosystems for the assimilation and conversion of pollutants is not well-known.

The prospect of opening the Onakawana deposits and the planned development by the Province of Quebec of hydroelectric power sources in the area east of James Bay, will focus attention on the area, with its considerable potential in pulpwood, minerals, and water resources. The increasing demands for energy and food constitute pressures which may induce the eventual industrialization, land development and urbanization of this vast area, with attendant threats to the environmental quality and its complex ecosystem.

The Province of Quebec has undertaken, or is planning, more intensive ecological studies of the natural environment.<sup>(17)</sup>

The Ontario Water Resources Commission together with the Federal Government have carried out a five-year water resource study<sup>(18,19)</sup> but no ecological studies. The former Lands and Forests has initiated plans to carry out ecological studies

in this area.<sup>(20)</sup> Initial phases have begun and a preliminary report on one aspect (wildlife inventory) has been submitted.<sup>(21)</sup> The impact on land and the ecosystems, if the Onakawana lignite field is developed, is concerned with:

(1) The loss of the wilderness values of the area a result of the probable open pit mining activity.

(2) The making of a large man-made body of water which may or may not be detrimental.

Notwithstanding the fact that some environmental studies are currently underway or planned, knowledge of basic biological processes in these undeveloped northern regions is still scarce. Consequently, it is recommended that significant development of the region should be preceded by a comprehensive investigation.

## 2.2 Oil

### 2.2.1 Water Pollution

Oil production produces a very small impact on the aquatic environment in Ontario. At present, drilling is banned on all of the Great Lakes except Lake Erie, from which gas is taken. In the event that oil production is allowed on Lake Erie or the other Great Lakes, the consequences on the aquatic environment could be significant and would have to be evaluated in detail. The environmental concern centers about the possibility and consequences of accidental

oil spills during drilling and production operations. Such a prospect should be the subject of an Environmental Impact Statement.

2.2.2 Air Pollution

To date the oil producing areas have not produced significant air pollution problems. No future problems are expected unless massive new deposits are located.

2.2.3 Impact on Land

The impact on land from oil drilling activities is concerned with:

- (i) Staking and locating procedures in the field.
- (ii) Access road location and construction to the drilling and well sites and line cutting, etc., in connection with geological and magnetometer surveys.
- (iii) Location of drilling sites.
- (iv) Waste-disposal practices.
- (v) Prevention of accidental spills and fires.

In the above, the main goals are to minimize the impact on forests, fish and wildlife habitat, landscape and aesthetic values through the application of approved plans and methods before, during and after the various stages of action required in the exercise.

Should oil or gas deposits in Northern Ontario be located, broad-based ecological studies, as outlined previously for the Onakawana area, should be carried out before development proceeds.

2.3

### Gas

Gas wells in Ontario are primarily restricted to offshore drilling rigs in Lake Erie. These rigs have presented a hazard to fishing gear in the past but are now fitted with equipment to fend off nets. These wells have not had a significant impact on the aquatic environment. At present most of the sources are distant from population centers and thus present a minimum air-pollution problem.

2.4

### Uranium

Hundreds of deposits of uranium-thorium minerals are known to occur in Ontario. At the present, however, production comes only from Elliot Lake and Bancroft areas. By 1991 Canada may have 30,000 to 50,000 MW of installed nuclear power plant capacity of the CANDU type. As a result the total nuclear fuel requirements will be modest compared to known reserves. The world's total nuclear power plant capacity may be over 30 times that of Canada; consequently, the availability of world markets and the desire for exports may determine if a significant quantity of Ontario's uranium is to be mined, and what the subsequent impact to the environment may be.

The discussion below covers the environmental impact of mining and milling uranium because this first processing step occurs in the mining areas. The impact of further refining the uranium ore is discussed in the next section.

#### 2.4.1 Water Pollution

The mining of uranium results in a significant impact upon the aquatic environment. Vein and pegmatite deposits tend to be relatively small and do not contain significant (from an environmental standpoint) quantities of re-active (iron) sulfide minerals. The Bancroft deposits are of this type. Serious water quality problems such as the generation of acid mine drainage do not occur as a result of mining and milling these deposits.<sup>(22)</sup> Approximately 80 percent of the present Canadian production, however, comes from the pebble conglomerates of the Elliot Lake district. These conglomerates, unfortunately, contain significant concentrations of (iron) sulfide minerals which, at present, have no economic value. Discarded as waste, these sulfides react to form acid-producing water soluble salts, causing mine-drainage problems.<sup>(22)</sup>

The disposal of uranium mining wastes, using practices which were considered to be standard in the mining industry, has resulted in serious long-term radiological and chemical pollution of the waters of the Serpent River basin.<sup>(4)</sup>

The main sources of the problem are the waste-water discharges from both active and abandoned tailings areas, which have resulted in increased radioactive Ra-226 levels in almost all waters of the basin, severe depression of pH and excessive increases in dissolved solids, sulfates and nitrogen levels, and sharp reductions in fish population and other forms of aquatic life.

The most significant impairment was evidenced by increases in RA-226 in the water by factors of 50 to 200 over the background levels in certain lakes, which decreased linearly with distance downstream from the emission location. Average RA-226 levels in the basin are shown on Figure 3. Levels above 3 pCi/l exceed the desired water quality value. Since changes in other water quality parameters generally followed a similar pattern, the Ra-226 distribution can be used as a general indicator of water pollution in the basin.

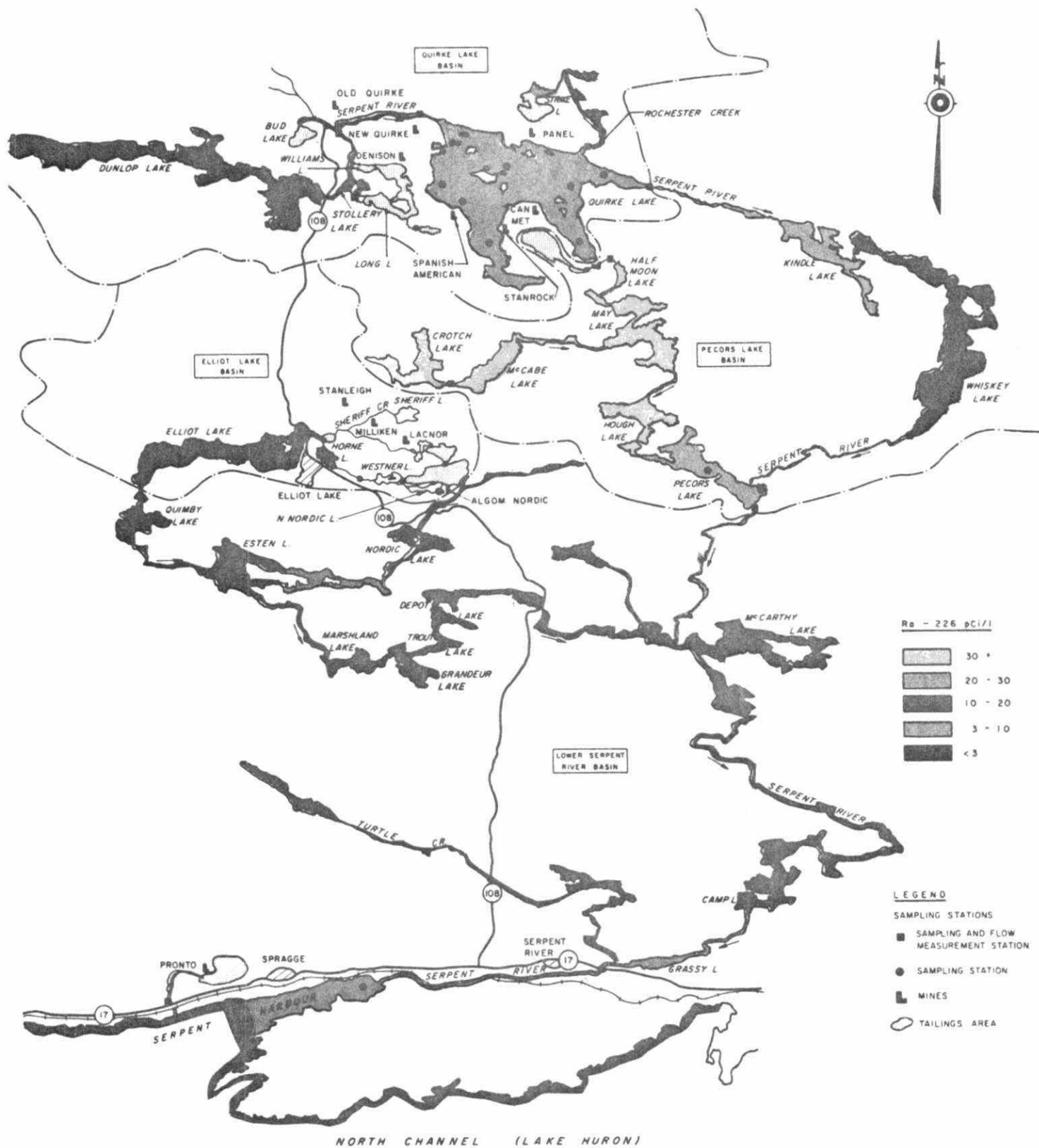
Significant quantities of radioisotopes have been concentrated by the aquatic organisms. Although some radioactivity was absorbed by fish, consumption of fish flesh appears to present no public health hazard. Finally, the residents in uranium mining areas do receive slightly higher doses of radioactivity than persons in the rest of the Province. The main source of the increased dose is the use of water.

The main impairments in the chemical quality of the water were the serious depression of pH and the 8 to 15 fold increases over background levels of dissolved solids, hardness, sulfates and nitrogen. The flow-through time for the largest lake in the system is estimated to be about 3 to 4 years. Thus, it may take several years before the effects of neutralization of the seepage and wastes can be measured. However, once the pH levels in the watershed are restored, ammonia may become a serious hazard to

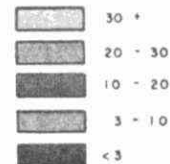
Table IV summarizes the pollutant waste load for the Elliot Lake region, corresponding to a production of 4500 tons of uranium oxide. Without corrective measures these wastes will increase directly with increasing production.

In the future, the uranium mining industry must revise its practices for use of water and waste disposal systems. The following steps are necessary for the protection of environmental quality in the mining areas:

- (i) Stabilization and maintenance of all abandoned tailings areas to secure, in perpetuity, their containment including isolation and cover, erosion control and, as required, treatment of seepage and runoff should be provided by the mining companies or their successors responsible for the disposal sites. Provincial legislation dealing with stabilization of tailings areas by vegetation or other methods should be extended to include abandoned areas and, as required, treatment of seepage and runoff.
- (ii) Mining companies should pursue the use of improved waste treatment techniques such as sulfide removal, and if necessary, ion exchange, reverse osmosis, etc., should be considered to improve the chemical quality of mill wastes and tailings. First priority should be given to the control of pH and toxic



Ra - 226 pCi/l



#### LEGEND

- SAMPLING STATIONS
- SAMPLING AND FLOW MEASUREMENT STATION
  - SAMPLING STATION
  - ⬚ MINES
  - TAILINGS AREA

TABLE IV

Waste Loading into Serpent River Basin (1966-1969)<sup>(4)</sup>

Type		Yearly Average
Ra-226	microcuries/day	4,300
Alpha Emitters	microcuries/day	39,000
Beta Emitters	microcuries/day	38,700
Dissolved Solids	lb/day	301,000
Total Nitrogen	lb/day	8,300
Sulphates	lb/day	171,000
Iron	lb/day	2,100
Chlorides	lb/day	8,500

compounds such as heavy metals and ammonia.

- (iii) Use of lake basins for containment of tailings at new mining locations should be prohibited.
- (iv) Further studies are needed to examine the total human intake of radioactivity through air, food and water in those areas where waters containing significant quantities of radionuclides are used for domestic water supply. It is expected that the radiation dose resulting from short-term use of these supplies may not present a significant hazard to health; however, it would be advisable to consider alternate supplies since any unnecessary exposure to radioactivity should be kept to a minimum.
- (v) Further studies are needed to define the levels of dissolved solids, particularly sulfates, necessary for restoration and maintenance of a healthy balance of the aquatic life.

#### 2.4.2 Air Pollution

In some areas of the world airborne radioactive substances have been identified as responsible for increased occasions of lung cancer.<sup>(23)</sup> In mining uranium the main problem is gaseous radon and its decay products. Forced ventilation through stacks is usually used with air-cleaning equipment and as a result, the quantity of airborne dust released to the atmosphere is usually very small. Dilution in the

atmosphere makes their concentrations insignificant relative to the amount of these gases normally present.

While the residents of the uranium mining and milling areas are exposed to somewhat higher levels of radioactive wind-blown particles, this is a minor source and does not represent a serious health problem.<sup>(24)</sup> Future increased levels of uranium mining will increase the atmospheric levels of radioactive substance.

#### 2.4.3 Impact on Land

The impact on land from uranium mining activities is concerned with:

- (i) Prevention of increase of radioactivity in soil, plants and animals.
- (ii) Disposal of the mine wastes in or over the land.
- (iii) Staking procedures in the field and access-road location and construction for prospecting and mining.

In the above, the main goals are to minimize the impact on plants, wildlife habitat, landscape and aesthetic values through the application of approved plans and methods.

### 3. Impact of Transporting Fuels

#### 3.1 Coal

The transportation of coals does not create environmental problems, but unloading and storage of coal results in localized wind-blown dusting. This can be partially controlled by the use of additives. Further, the use of air

curtains (that is sheets of moderate velocity air) shows good promise for the containment of such dusts.<sup>(25)</sup> New installations should be equipped for the prevention of wind-blown coal. It is believed that present technology can control these dusting problems in the future. Large consumers of coal require extensive stockpiles (as shown in Figure 4), and these together with their continuous relocation produce local air-pollution problems which are of major importance to the neighbouring residents up to about two miles. Future stockpiles will become both larger and more numerous, but this problem can be handled in the future by existent technology.<sup>(26)</sup>

### 3.2

#### Oil

A potential danger to the aquatic environment is the possibility of a major spill arising from either a pipeline break or a collision between vessels transporting oil. In the report of the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, it is stated:

"although the likelihood of a major oil spill on the lakes is fairly remote, the risk is real and continuing. The loss of 1000 tons of bunker fuel or similar petroleum product would be enough to pollute extensive areas of the lake and many miles of shoreline. The immediate consequences of such a disaster

FIGURE 4



View of Lakeview Generating Station, including coal pile, near end of shipping season.

would be the damages to water supplies, bathing beaches and other recreational facilities, as well as the destruction of large number of waterfowl. The effects of oil pollution on the littoral ecology are largely unknown but experience elsewhere indicates that some of the methods used to remove or disperse the oil are more harmful than the oil itself."<sup>(27)</sup>

In order to minimize the adverse effects which would almost certainly result from a majorspill, a comprehensive program for combatting spills must be developed. In this regard, an Interim Province of Ontario Contingency Plan for spills of oil and other hazardous substances has been formulated<sup>(28)</sup> but has not yet been established as effective and viable solution to the spill problem.

Because a massive spill on the Great Lake or connecting waterways might also affect the U.S.A., both Federal<sup>(29)</sup> and International<sup>(30)</sup> Contingency Plans have been developed. Depending on the severity of a spill, the Province of Ontario Contingency Plan only might be implemented, however, if an escalated response was necessary, the Federal Plan would be implemented. If U.S. waters were being affected, then the International Contingency Plan would be implemented. All three of these Contingency Plans have been formulated to complement each other in the event that an escalated response is necessary.

Several separate problems attend oil pipelines. Because the pipelines carry very large volumes of oil between gate valves, this presents a serious but local problem from the released oil on the land, unless it is close to a population center in which case the danger of fire is considerable. Environmental damage in oil-soaked areas usually results in denuding of vegetation, especially if crudes or light fuels are involved.

Experience in the U.S. indicates that ground water may be contaminated in instances of disposal of oil-soaked material or dirty oil by burying. Although evaporation would be of assistance in a surface spill, the shallow nature of much of Ontario's ground water could result in contamination of ground water.

### 3.3

#### Gas

There are no water-or air-pollution problems associated with the transportation of natural gas with the exception of an accidental release of the fuel. The problems attendant to production of gas through coal gasification are described later.

The impact of transporting and processing gas by pipeline is concerned with:

- (i) Location of the pipelines.
- (ii) Access road location and construction
- (iii) Location of gas-line pumping stations and other facilities.

- (iv) Waste-disposal practices.
- (v) Maintenance procedures and methods.
- (vi) Prevention of accidental spills and fires.

In the above, the main goals are to minimize the impact on forests, fish, and wildlife habitat, landscape and aesthetic values through the application of approved plans and methods before, during and after the various stages of action required is the exercise. A summary of past practices and desired procedures for pipeline construction and maintenance is given in reference 31.

#### 4. Impact of Processing of Fuels

##### 4.1 Coal

Processing of coal for the production of coke and coke oven gas results in significant environmental problems which are discussed in the action of industrial energy use.

##### 4.2 Crude Oil

Crude oil at present is not used in its natural form, but is processed into a variety of end products. In Ontario the bulk of the crude oil is imported from Western Canada and to a minor extent from Venezuela. In 1970 production from Ontario fields supplied less than 1% of the total refinery intake.<sup>(32)</sup>

Refineries process crude oil to produce fuels for the transportation sector, fuel oils for utilities, household commercial and industrial consumers and provide feedstocks for the petrochemical industry. In many

cases petrochemical feedstock is used captively in highly integrated refinery and petrochemical operations. It is therefore difficult to single out the environmental impact originating from the processing of crude oils alone, since the petrochemical operations also contribute in varying degrees to the overall environmental impact. Within these limitations the environmental impact of refinery operations resulting from the processing of crude oils will be discussed.

In Ontario there are presently seven refineries with a total capacity of about 400,000 barrels per day. Three refineries with about 60% of the capacity are aggregated in the Sarnia area. The remaining operations are located along Lake Ontario between Oakville and Mississauga.

The increasing energy demands of the Province will result in increasing refining capacity (See Table V) in order to meet the increasing demands of automotive and aviation fuels and fuel oils for the production of heat, steam and electrical energy by the various consumers. This increase in capacity potentially may result in increasing emissions of pollutants, unless refining technology is modified and abatement of pollutant emission is improved.

#### 4.2.1 Water Quality

Refineries are the source of a variety of pollutants discharged into some of the Province's water bodies,

TABLE V Projected Ontario Refinery Capacity and Emissions into the Atmosphere

Year	Distill. through (1000 B/yr.)	Refinery Emissions (tons/yr.)**			HC Losses to Atmosphere from Distribution Systems*** (tons/yr.)	
		HC	SO <sub>2</sub>	CO	No Control	Control
1970	135,700	67,500	115,300	71,000	98,500	61,200
1975	171,000	85,000	145,000	90,000	126,000	78,500
1980	215,000	107,000	183,000	113,000	157,000	97,000
1985	270,000	130,000	230,000	140,000	182,000	112,500
1990	324,000	161,000	275,000	169,000	236,000	146,000

\*Data from references 32 and 33

\*\*Estimates based on 1970 capacity and projected oil demand for Ontario, assuming

- (1) Same future proportion of home market supply by Ontario refineries as in 1970.
- (2) Emissions directly proportional to capacity.

\*\*\*Data based on information forwarded in the Air Management Branch and PACE subcommittee meetings on hydrocarbon emissions. Figures do not include automobile tank filling losses.

i.e. the St. Clair River and Lake Ontario. Table VI summarizes the main pollutants discharged into the water. In addition estimates were made of refinery waste discharges in 1981 and 1991 for both current refining and treatment methods and the best refining and waste treatment processes available at that time.

As a result of continuing advances in waste treatment and process technology, waste discharges into the water bodies are expected to decrease in the future despite the increase of refinery capacity. However, because of the large quantities of oil and refinery products handled at refineries, there is a significant potential for accidental spills of oil. Consequently, provision of contingency plans for accidental spills will become increasingly important in the future.

#### 4.2.2 Air Quality

Oil refineries produce a number of air pollution problems. Refineries and their distribution system are a major source of hydrocarbon emission and contribute in varying degrees to the total emission of sulfur oxides, carbon monoxide, nitrogen oxides and particulates. In addition, refineries may be an irritating source of malodorous compounds.

The emission of main atmospheric pollutants was estimated on a basis of data of refinery surveys (Table V). Projections of refinery emissions were made under the assumption that existing control technology for refinery

TABLE VI Projection of Oil Refinery Waste Discharges into Water

Pollutant	DISCHARGE				
	1971	1981		1991	
		Current Practices	Best Practices	Current Practices	Best Practices
Waste Flow mgd	180	280	80	360	120
COD* lbs/day	71,500	110,000	24,000	153,000	36,000
Ether Soluble Oils lbs/day	9,000	15,000	0	18,000	0
Phenols lbs/day	200	300	8	400	12
Total Nitrogen lbs/day	30,000	45,000	800	60,000	1,200
Ammonia lbs/day	5,000	8,000	800	10,000	1,200

\* COD is the chemical oxygen demand which is the amount of oxygen required for the chemical oxidation of organics in a liquid.

emissions will remain unchanged. Hydrocarbon emission of distribution systems was estimated assuming no further abatement and considering a reduction of 40%.

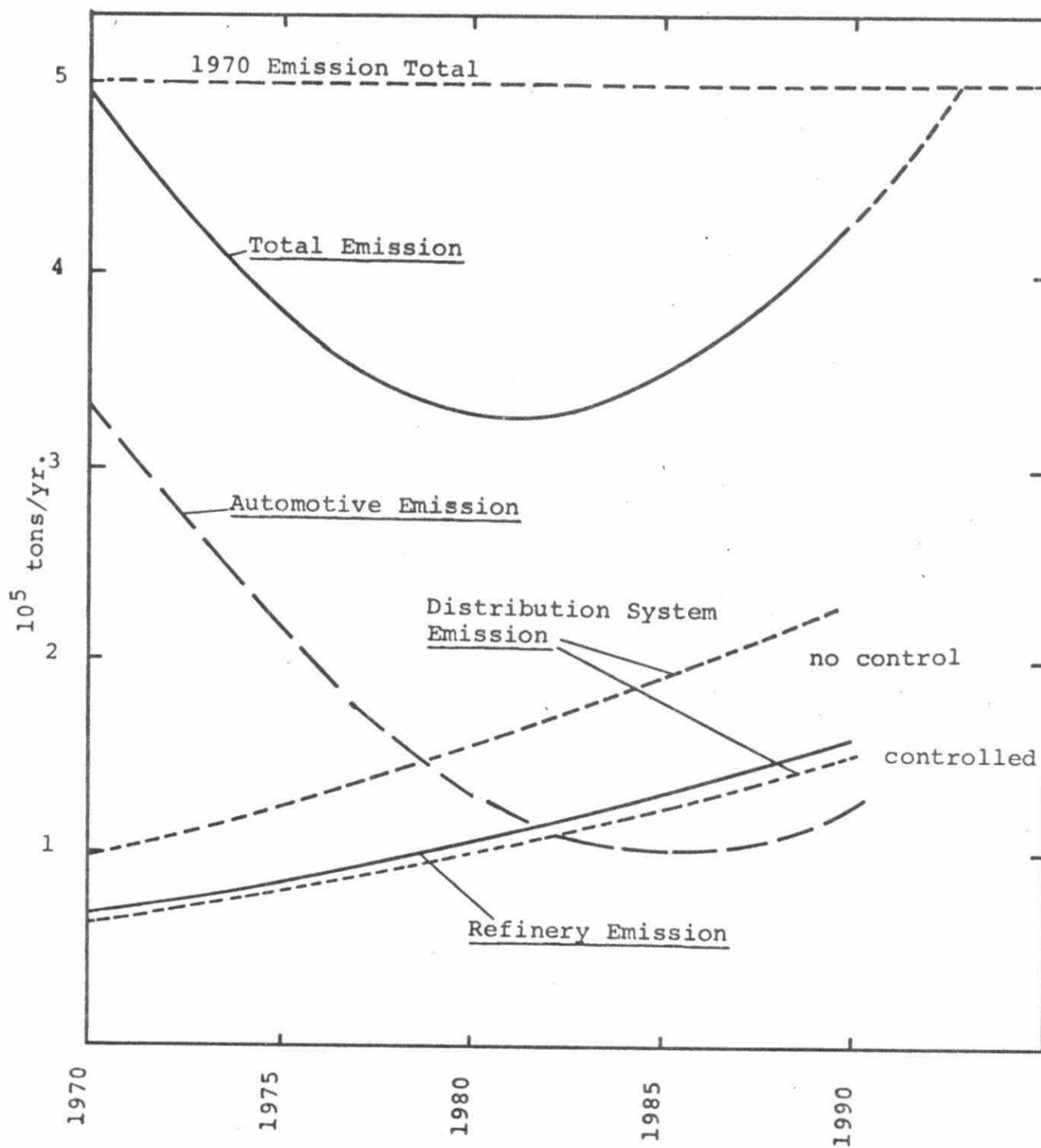
Figure 5 projects HC emission of refineries and their gasoline distribution system relative to the largest hydrocarbon (HC) emission sources, i.e. automobiles, for the next 20 years.

The two main sources of HC emission of refineries and their distribution systems are cone roof storage tanks and loading facilities of volatile HC's. Effective control for a substantial reduction of HC emission of both sources are feasible by equipping cone roof storage tanks with "floating" roofs and by avoiding "splash" loading of tank cars and storage tanks.

In a collective effort refiners agreed to reduce emission of distribution systems by 40% within the next 9 years. However, increasing gasoline sales and corresponding increasing HC losses will result in increasing HC emissions. By about 1980 emissions from distribution systems are expected to be back at 1970 levels and to increase thereafter. Capital expenditures for a 40% reduction of HC emission were estimated to be \$0.50 to \$0.55 per recovered gallon HC per year. A maximal reduction of HC emission of about 75% is feasible, but the need to reduce HC emission has not been demonstrated yet.

Figure 5

Projected HC Emission in Ontario by Source



Due to the complexity of refinery operations, the reduction of refinery HC emission is difficult to estimate. Despite increasing controls, HC emission may be expected to increase as refining capacity will increase. Refineries and their distribution systems will be the main emission source for hydrocarbons after about 1983. As a result the combined total HC emission of the three major sources is expected to be back at the 1970 emission level by about 1995 (Figure 5).

Emission of sulfur dioxide are mainly a function of the sulfur content of the crude oil being processed. Sulfur oxides ( $SO_x$ ) and nitrogen oxides ( $NO_x$ ) originate from combustion sources including catalyst regenerating units, boilers and process heaters. Refineries have a choice of a variety of strategies to comply with  $SO_2$  emission standards such as:

- (i) Use of low sulfur grade fuel
- (ii) Desulfurization of residuum
- (iii) Stack Height.

Refineries in general use their own heavy crude oil cuts for power generation. Therefore their  $SO_2$  output depends largely on the sulfur content of the residuum fuel oil. Desulfurization of residuum oil is feasible and costs about 11 to 16¢ per MM BTU for a 70% reduction of the sulfur content.

NO<sub>x</sub> emission is presently considered to be of relatively minor magnitude. If unabated, NO<sub>x</sub> emission may be expected to increase but will continue to be a minor fraction of the overall NO<sub>x</sub> emission. A reduction of NO<sub>x</sub> emission of up to 50% is feasible by the use of low-excess air furnaces. Low-excess air furnaces are more efficient than conventional furnaces and therefore reduce the cost of heat while reducing NO<sub>x</sub> emission.

Better fuel efficiency of low-excess air furnaces should provide an incentive for industry to favor low-excess air furnaces for grass-root facilities.

The main source of CO and particulate emission is the flue gas from the catalyst regenerators of the catalytic cracking units. Flue gas may contain up to 8% CO. Modern refineries are equipped with CO boilers and provisions for flue gas particulate recovery, which nearly eliminate CO emission and largely reduce particulate emission. Such refineries therefore are only a minor source of total CO emission. CO emission by older refineries may be expected to decrease as uneconomic operations are phased out. Particulate emission is of minor magnitude, although excessive emission does take place occasionally upon process upsets in the catalytic cracking units.

Malodorous compound emission is a local nuisance and a source of many complaints. Usually poor household

practices could be accounted for this problem. In refinery surveys such practices were identified and recommended to be discontinued.

#### 4.2.3 Impact of Refineries on the Environment

Although ambient air concentrations of gaseous HC have not demonstrated yet direct adverse effects on human health, they are one of the two main components responsible for photochemical smog. Parts of the photochemical smog complex are intermediate reaction products such as photochemical oxidants and aldehydes, which are known to cause human discomfort and plant damage.

At present smog does not constitute a health problem in Ontario. However, tobacco plants and white beans were affected adversely in southwestern Ontario as a result of the presence of photochemical oxidants. Since the areas affected are mainly agricultural, it is likely that the injurious oxidants or their precursors originated elsewhere.

Presently there exist no provincial air-quality criteria for HC's. A federal standard of a maximum concentration of 0.24 ppm HC during 3 hours was proposed in accordance with the observation that in the Los Angeles basin HC concentrations of as low as 0.3 ppm resulted in photochemical oxidant formation of a concentration of up to 0.1 ppm for an average period of one hour. However, Ontario's climatic conditions differ substantially from

the smog favoring atmospheric conditions of Los Angeles, resulting most likely in a different HC threshold concentrations for photochemical smog formation. Maximal total HC concentrations in Ontario were 8 to 18 ppm in 1970. This concentration range includes also naturally occurring methane, which is a very inert HC in photochemical reactions. The available data for total HC concentrations therefore are of little value for correlating HC concentrations in air and occurrence of photochemical smog. At present, no prediction of the future impact of increasing HC emission from refinery operations may be made and no environmental limit for HC concentration in ambient air may be established.

Refineries are prone to violate the  $\text{SO}_2$  air quality standards of Ontario. Presently, the one-year average  $\text{SO}_2$  levels in many urban areas of Ontario exceed ambient air quality standards. Although it is recognized that refineries are not a major source of overall  $\text{SO}_2$  emission, the over-saturation of air with  $\text{SO}_2$  indicates the need of strict compliance with the present standards.

Both  $\text{NO}_x$  and particulate emission may be expected to increase but will continue to be a minor fraction of the  $\text{NO}_x$  and particulate emission. The emission of CO is minor compared with other sources and does not present an air quality problem.

#### 4.3

##### Uranium

The processing of nuclear fuel, beyond the milling operation, causes a number of potential pollution problems. (34)

The refining of ore concentrates received from the mills and the production of uranium dioxide ( $UO_2$ ) for use in the CANDU system result in solid wastes and spent chemical solutions requiring treatment and disposal. Further, the production of heavy water, used by moderators in the CANDU system, also represents a pollution potentials, and the reprocessing of fuel elements could lead to serious waste-disposal problems.

#### 4.3.1

##### Water Pollution

- (i) Uranium Dioxide ( $UO_2$ ) Production The refining of ore concentrate received from the mills and the production of uranium dioxide ( $UO_2$ ) for use in the CANDU system is carried out as part of Eldorado Nuclear's refinery operation in Port Hope. Due to lack of market, the  $UO_2$  plant has been closed for three years, and no current operation data is available. At present, uranium dioxide for existing contracts is manufactured from a stockpile of the intermediate product, ammonium diuranate. The ore concentrate contains 15 - 35% impurities which are removed, precipitated with lime, and disposed of as solids. In the past, the leaching of radium and arsenic from the dump sites

has been a problem. The problem has arisen as a result of poor land-disposal-practices utilized prior to 1967. A leaching problem is not expected to arise from the cut and fill process used since 1967. The feasibility of treating the wastes, prior to the lime treatment, to precipitate the arsenic and radium in forms which will be less susceptible to leaching is also under study.

Spent chemical solutions containing nitrate and ammonium ions represent a further disposal problem. Utilizing the waste loading figures of 620 lbs. nitrate ion and 220 lbs ammonium ion per ton of  $UO_2$  produced and the projected requirement of 10,000 tons of  $UO_2$  per year for Ontario reactors in the year 2000, it can be estimated that 3100 tons per year of nitrate and 1125 tons per year of ammonium will be discharged as by-product. It is expected however that a satisfactory method of treatment will be developed before the expected waste loadings materialize.

In summary, it is believed that treatment methods will be developed that will prevent the wastes from the refining of uranium having any significant effects on the water quality by 1991.

- (ii) Heavy Water ( $D_2O$ ) Production - Deuterium, a heavy isotope of hydrogen, is present in fresh water at a concentration of about 150 mg/l. The process for separation and concentration of this naturally occurring deuterium depends on an enrichment process based on the temperature-dependent equilibrium between hydrogen, deuterium, and hydrogen sulfide ( $H_2S$ ).

The Bruce Heavy Water Plant, located at Douglas Point, Ontario, has been designed to produce 800 metric tons per year of heavy water from a feed of about 13,500 U.S. gpm of Lake Huron water. This plant, which will be the largest of its type in the world when completed, will have a total inventory of 1,200 tons of hydrogen sulfide in the process equipment when in operation.

Under normal circumstances, the only  $H_2S$  released in the liquid waste from the heavy-water plant will be present in the 13,500 ~~gpm~~ process waste stream. This stream, with a design maximum  $H_2S$  concentration of 1 mg/l, will be discharged into one of two lagoons each of which has a three-hour retention time. Because the lagoons are aerated, it is expected

that the concentration of  $H_2S$  will be reduced to an extremely low level, although precise estimates of the lagoons performance cannot be made due to a lack of data for  $H_2S$  treatment systems of this type.

There will be two other significant aqueous waste streams from the Bruce Heavy Water Plant and these are the discharges from the two separate cooling water systems. These discharges, of 75,000 U.S. gpm each, will normally contain no  $H_2S$ . It is to be expected, however, that minor leaks may occur and if so, these will result in some  $H_2S$  gaining access to the cooling-water flow.

Because of the possibility of some  $H_2S$  leakage into the cooling water, and because it is also possible for the lagoon effluent to contain some residual  $H_2S$ , the OWRC has approved the waste treatment facilities on the condition that the maximum loading of  $H_2S$  to Lake Huron over a one hour period will not exceed 18 pounds. This loading corresponds to an  $H_2S$  concentration in the combined effluent of 0.09 ppm, which is within the limits considered safe for fish.

It is possible, of course, that failure of certain process equipment could result in "spills" of  $H_2S$  in concentrations far above those expected during normal operation. The probability of such failure is low, however, and therefore the plant is not expected to present a serious threat to the aquatic environment.

#### 4.3.2 Air Pollution

Airborne effluents from nuclear fuel processing beyond the milling operation vary in terms of volume, concentration, and chemical composition, depending upon their origin. All these operations in fuel processing are potential sources of radioactive airborne dust.

- (i) Fuel-Fabrication Plants - Dust or fumes are controlled by conventional gas cleaning equipment.<sup>(35)</sup> Dust emission consist essentially of uranium or thorium compounds involved in the process. The gases evolved from a fuel-processing plant are usually contaminated with such chemicals as nitric acid and organic solvents, as well as with fission products, depending upon the particular process employed. Since fuel processing requires treating effluent gases to remove minute quantities of radioactive materials, it removes many of the nonradioactive components as well. In these operations, the relatively high economic value of the product

material makes it unlikely that significant air contamination will occur in normal operation conditions.

- (ii) Fuel-Reprocessing Plants - As yet, there are no fuel reprocessing plants in Ontario, however, it is a reasonable assumption that such a plant will be established during the time interval of this study. Consequently, some of the environmental problems, which could arise, are outlined here. In order to extend the supply of nuclear fuel, reprocessing is highly desirable. When a reactor core has reached the end of its useful life, only a small amount of  $^{235}\text{U}$  will have been consumed by fission and an additional amount of  $^{238}\text{U}$  will have been transformed to  $^{239}\text{Pu}$ . The fuel with its inventory of fission products, may then be removed from the reactor and transported to a chemical processing plant where uranium and plutonium are recovered for use in a new fuel elements.

Even though the fuel is stored to provide time for radioactive decay, a large quantity of highly radioactive material is still present when the fuel reprocessing begins. The greatest potential danger of air contamination arises at a fuel reprocessing plant.

The most critical problem of air pollution from a potential fuel reprocessing plant is possibly the release to the atmosphere of  $^{85}\text{Kr}$  (half-life of 10.8 years). Location of the fuel-reprocessing plant in the site of favourable weather conditions and the use of high stacks are possible methods to keep  $^{85}\text{Kr}$  ground-level concentrations below a permissible ambient level of  $10^{-7}$  mci/cc. Eventually, the discharge of noble gases may be prohibited during the reprocessing of nuclear fuel. A number of methods for  $^{85}\text{Kr}$  removal from gas streams are available and include; room temperature absorption on charcoal, silica gel, or molecular sieves, low temperature absorption on charcoal or molecular sieves, cryogenic distillation and scrubbing, extraction by liquids, and thermal diffusion. These processes are at various stages of development, and most can remove more than 90% of the  $^{85}\text{Kr}$ .

Gases can be stored for radioactive decay until meteorological conditions are adequate for dilution and dispersion in the atmosphere. This technique will probably be favoured by the nuclear industry, but should be officially discouraged.

The fact that radioactive substances can cause damage to people, plants and animals and can

enter food chains is well-known. Since its inception, the nuclear industry has been aware of the potentially hazardous effects of its wastes. Standards for permissible concentrations of radioactive pollutants in the environment have been established. However, the permissible release standards are to be questioned because they are 10 to 100 times higher than what is actually being released. This situation is discussed more fully in a subsequent section dealing with nuclear power plants. In any event, effective containment and disposal methods are absolutely necessary for fuel reprocessing plants.

- (iii) Heavy-Water Production - The operation of a heavy-water plant involves large quantities of hydrogen sulfide, which is used for the enrichment process.

During the normal operation of the plant there are continuous emissions of  $H_2S$  via a flare stack where provisions are made for combustion of the gas.

A summary of the sources of  $H_2S$  and possible ground level concentration emissions from a heavy-water plant is given in Table VII. In the event of an upset condition in the process, some of the equipment may have to be isolated

TABLE VII

Sources, Operations and Concentrations  
of  $H_2S$  Released from a Heavy Water Plant

Source/Operation	$H_2S$ Emitted to Flare	Ground-Level Concentrations of $H_2S$ p.p.m.	
		With Ignition	Without Ignition
Normal operation	yes	.001	.001
Storage and loading	no	-	-
Process draining	yes	0.33	1.3
Emergency venting	yes	0.81	100
Major failure	no	500	500

Data from reference 36.

and vented to the atmosphere via the flare system and consequently the ground-level concentrations of  $H_2S$  would exceed the Ontario Ambient Air Criteria of 0.25 ppm for one hour. The frequency of such upset conditions is unknown at this time, but it is expected to be higher at the start-up of the plant and decrease as more experience is obtained.

Emergency venting through the flare stack is a remote possibility, but in the event of such an occurrence, up to 900,000 lbs. of  $H_2S$  per hour would be released to the flare and the ground-level concentrations would exceed the criteria.

A major failure in a critical piece of equipment, (the rupture of a storage vessel) could cause the release of 400,000 lbs. of  $H_2S$  within an extremely short period of time.

Dangerous concentrations, which may severely affect human life, can be expected as far as 14 miles from the source. The probability of a major catastrophe is considered to be very low. A contingency plan to cope with such an event was developed.<sup>(37)</sup>

5. Impact of Utilization of Fuels and Energy

5.1 Impact of Electrical Power Generation

Figure 1 shows that over the next two decades electrical power generation will become the biggest single consumer of our energy resources, inasmuch as Ontario appears to have little further potential for hydro power except in the far north. Unfortunately, fossil-fuel or nuclear power plants produce a variety of emissions which pollute the air and they discharge large amounts of waste heat into the water or air.

Electrical utilities, including Ontario Hydro, have recognized the need for planning far in advance for future facilities. However, until a few years ago they have not had to take into account their overall effect on the environment. Although work on emission control techniques has been accelerated over the past four or five years, the presently available engineering technology is inadequate to meet our present needs of cleaner emissions. Power companies over North America are faced with increasing demands for electricity, but their plans for expansion and satisfying this demand are being blocked by citizen groups concerned with conservation and the environment. It appears probable that Ontario Hydro will face increasing pressure from the public in the future.

5.1.1 Air Pollution

5.1.1.1 Emissions by Fossil-Fuel Plants

The air pollutants emitted from fossil-fuel plants depend

upon the type of fuel used. The types and quantities of emissions from the burning of different fuels are shown in Table VIII. The lower levels of solid particulate and sulfur dioxide emissions result from the use of gas, which illustrates why many power plants in North America have been converted to this fuel. However, due to the fact that many organizations are solving their emission problem in this way, the supply of natural gas will become very restricted in approximately a decade or so if it is used as a general solution. Consequently, it already appears advisable to limit the use of natural gas to other situations where alternative emission abatement solutions would be prohibitively expensive.

Oil reserves appear sufficient for several decades, while the known reserves of coal indicate an adequate supply for several centuries. Consequently, we have concentrated on the effects of using primarily coal and secondarily oil, in future fossil-fuel plants.

- (i) Solid Particulates - Solid particulate emissions for all practical purposes are under reasonable control in large power plants (see Fig. 6). It is now largely a matter of satisfactory operation and strict compliance with the regulations. A number of systems are available for dust or fly-ash control. However, electro-

TABLE VIII  
COMPARISON OF QUANTITY AND TYPE OF EMISSIONS FROM PLANT BURNING  
COAL - OIL - NATURAL GAS

Pollutant	COAL lb/ton of Coal Burned			RESIDUAL OIL lb/1000 Imp.Gal. of Oil Burned			NATURAL GAS lb/million cu. ft. of gas burned		
	Central Station	Industrial	Domestic Commercial (Stoker)	Central Station	Industrial & Commercial	Domestic	Central Station	Industrial	Domestic Commercial
Aldehydes	.005	.005	.005	1.2	1.2	2.4	3.0	3.0	10.0
Carbon Monoxide	1.0	2.0	10	.05	.25	6.0	.4	.4	20
Hydrocarbons	.3	1.0	3.0	6.0	3.6	3.6	40	40	8
Other Organics	-	-	-	-	-	-	4.0	7.0	1.0
Oxides of Nitrogen	18	15	6.0	126	48-96	14.4	390	120-230	50-100
Sulphur Dioxide	38A	38A	38A	188B	188B	170B	0.6	0.6	0.6
Sulphur Trioxide	-	-	-	2.4B	2.4B	2.4B	-	-	-
Particulates	Depends on degree of control			9.6	27.6	12	15	18	19

Notes (1) A is the percent sulphur in coal (ie. in 2% S coal, the  $SO_2$  is  $38 \times 2 = 76$  lbs.)

(2) B is the percent sulphur in oil.

(3) Industrial represents industrial boiler houses.

Data from reference 38.

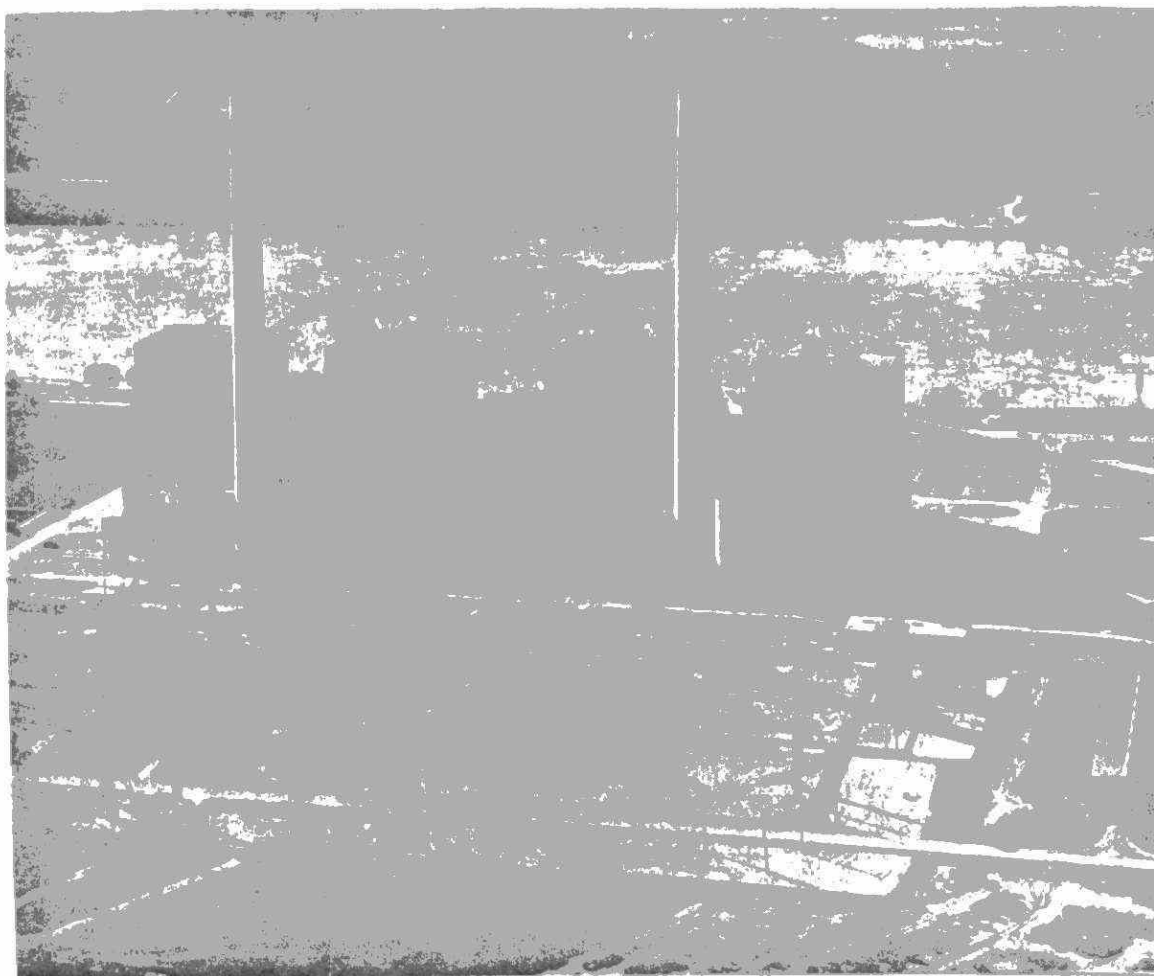
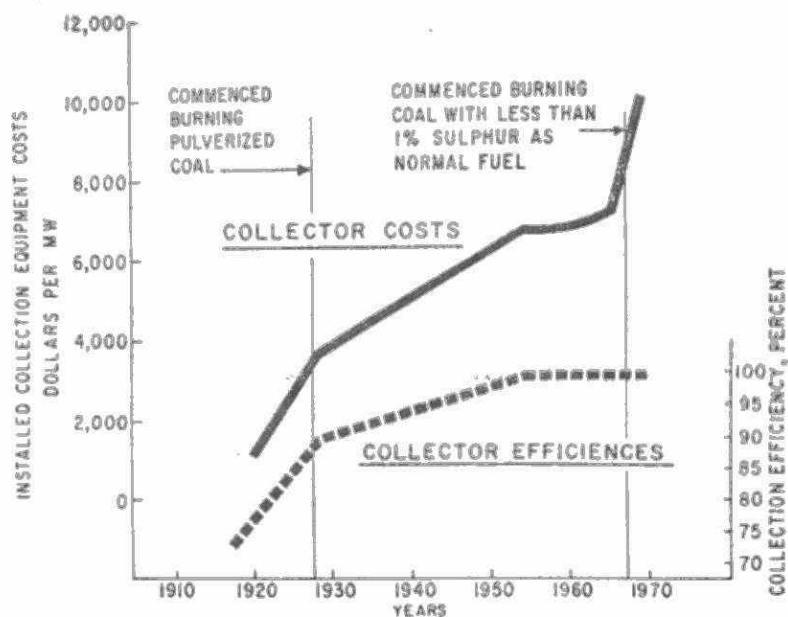


FIGURE 6. View of 2000 MW  
Lambton Generating Station



Increase in cost of dust-collecting equipment in the Con Edison system, after Ramsdell and Soutar.<sup>3</sup> The figures are corrected to present day costs, and include material and erection costs of collector, flues, support steel, and fly ash conveying facilities.

FIGURE 7.

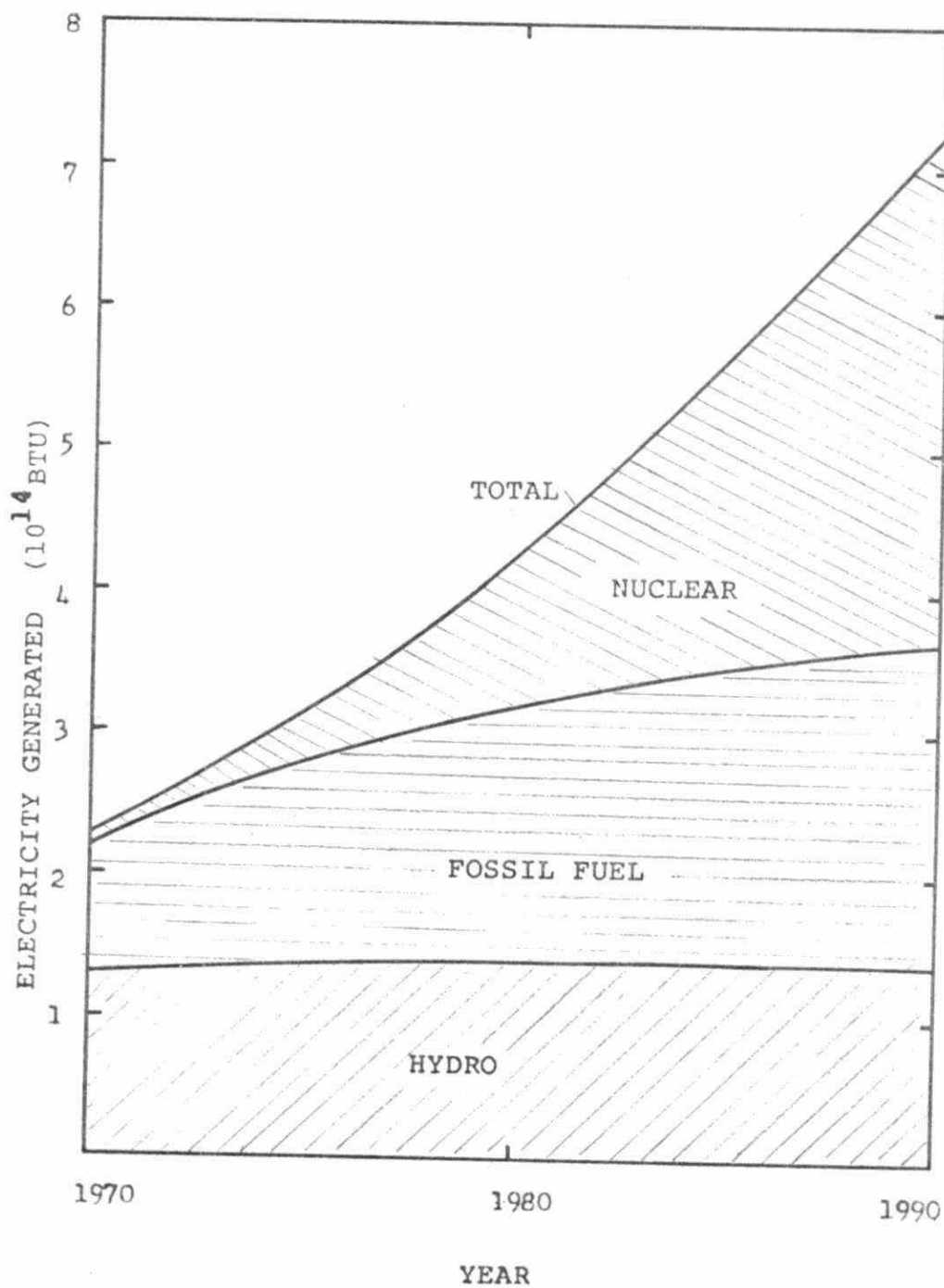
static precipitators offer the best long-term solution, even though they are massive and costly as shown in Figure 7. Ontario Hydro appears committed to this direction as indicated by the following quote from a recent publication,<sup>(31a)</sup>

"All the coal-fired stations are fitted with dust-collection systems to contain the fly-ash. The older stations have combined mechanical and electrostatic dust collections and the newer ones have electrostatic dust collectors only. The policy is to achieve a minimum of 99.5 percent dust-collection efficiency on all new boilers, but efficiencies are lower than this for some of the older installations."

(ii) Emission of Sulfur Dioxide

Sulfur dioxide control and abatement represents today's air-quality battleground for the electrical power industry.<sup>(39,40)</sup> In 1970 Ontario's fossil-fuel plants consumed about 10 million tons of coal to generate the equivalent of about  $0.9 \times 10^{14}$  BTU of electrical energy (Fig. 8). Assuming an average sulfur content of 2.4% this resulted in the emission of 470,000 tons of sulfur dioxide into the atmosphere. (Fig. 9) Sulfur dioxide emissions are expected to increase as more and more fossil fuel plants come

FIGURE 8. Rough projection of generation of electricity from primary energy sources

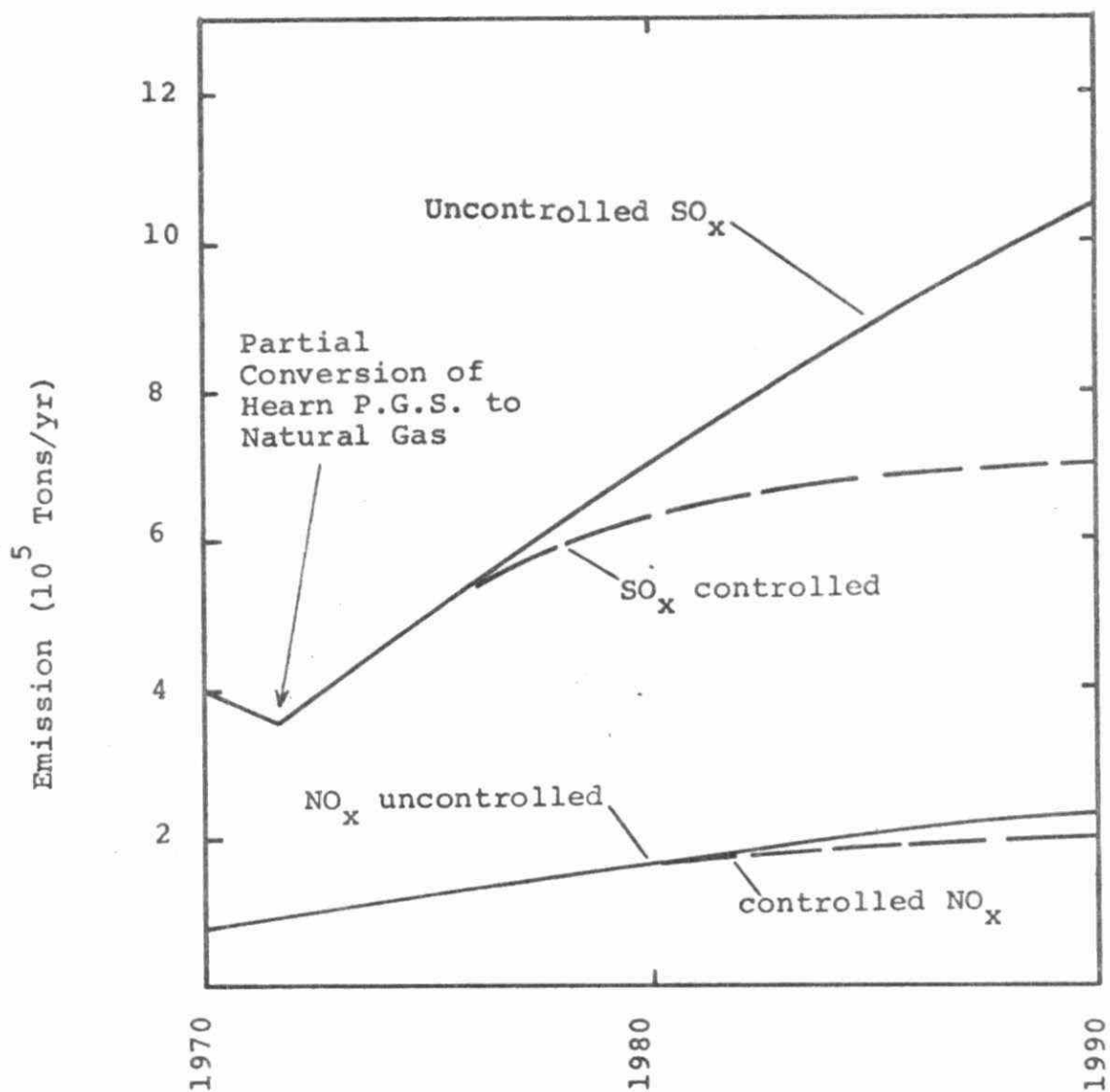


into operation. Without abatement, sulfur dioxide emissions will be in excess of 1 million tons per year before 1990. Assuming that  $\text{SO}_2$  control technology will become available by the mid-seventies, the reduced emission rate of  $\text{SO}_2$  is indicated by a dotted line in Fig. 9. The impact of  $\text{SO}_2$  emissions from power generating stations on the environment is severe. In 1970 for example, 77% of the  $\text{SO}_2$  emitted in the Metropolitan Toronto area originated from two power stations. During this period,  $\text{SO}_2$  ambient air-quality criteria were exceeded numerous times in Metropolitan Toronto. In 1971, when the R.L. Hearn Station was partially converted to natural gas, the  $\text{SO}_2$  emissions were reduced by about 54,000 tons. As a result, a significant improvement of Metropolitan air quality was observed as manifested by a steep decrease of times the  $\text{SO}_2$  ambient air quality standards were exceeded.

Numerous methods for the reduction of sulfur dioxide emission are being investigated. A comparative evaluation of these methods will be discussed in Chapter 5.1.1.2.

Figure 9

Estimated  $\text{SO}_x$  and  $\text{NO}_x$  Emissions by Ontario's Thermal Power Generating Stations.



(iii) Emission of Oxides of Nitrogen

Oxides of Nitrogen (mainly NO and NO<sub>2</sub> and collectively called NO<sub>x</sub>) are not being ignored by the electrical power industry in North America.

NO<sub>x</sub> forms in all high-temperature flames when nitrogen of the air reacts with active oxygen species in the flame. Generally, at higher temperatures more NO<sub>x</sub> is produced.

In 1970, about 53% of the NO<sub>x</sub> emitted by all energy consuming sources in Toronto came from the two electrical power generating stations<sup>(2)</sup>. NO<sub>x</sub> emissions by power generating stations therefore significantly contribute to the overall NO<sub>x</sub> level in ambient air. In 1970 the ambient air quality criterion for NO<sub>x</sub> was exceeded in Metropolitan Toronto on numerous occasions. The trends in total NO<sub>x</sub> emissions in the future are shown in Figures 9 and 10. Power generation plants are expected to produce a larger portion of the future NO<sub>x</sub> due to their more rapid growth. The present high ambient levels of NO<sub>x</sub> and the expected increase of NO<sub>x</sub> concentrations as discussed later indicates that power plants will have to reduce these emissions in certain areas by the end of this decade. Two basic procedures reduce NO<sub>x</sub> emissions, (1) burning

at a temperature that is as low as possible.  
or (2) operating the boiler furnaces to eliminate highly active forms of oxygen from the flame.

The Esso Research Corp. in the U.S. has completed an extensive three-year study evaluating future control techniques for  $\text{NO}_x$ . (41, 42)

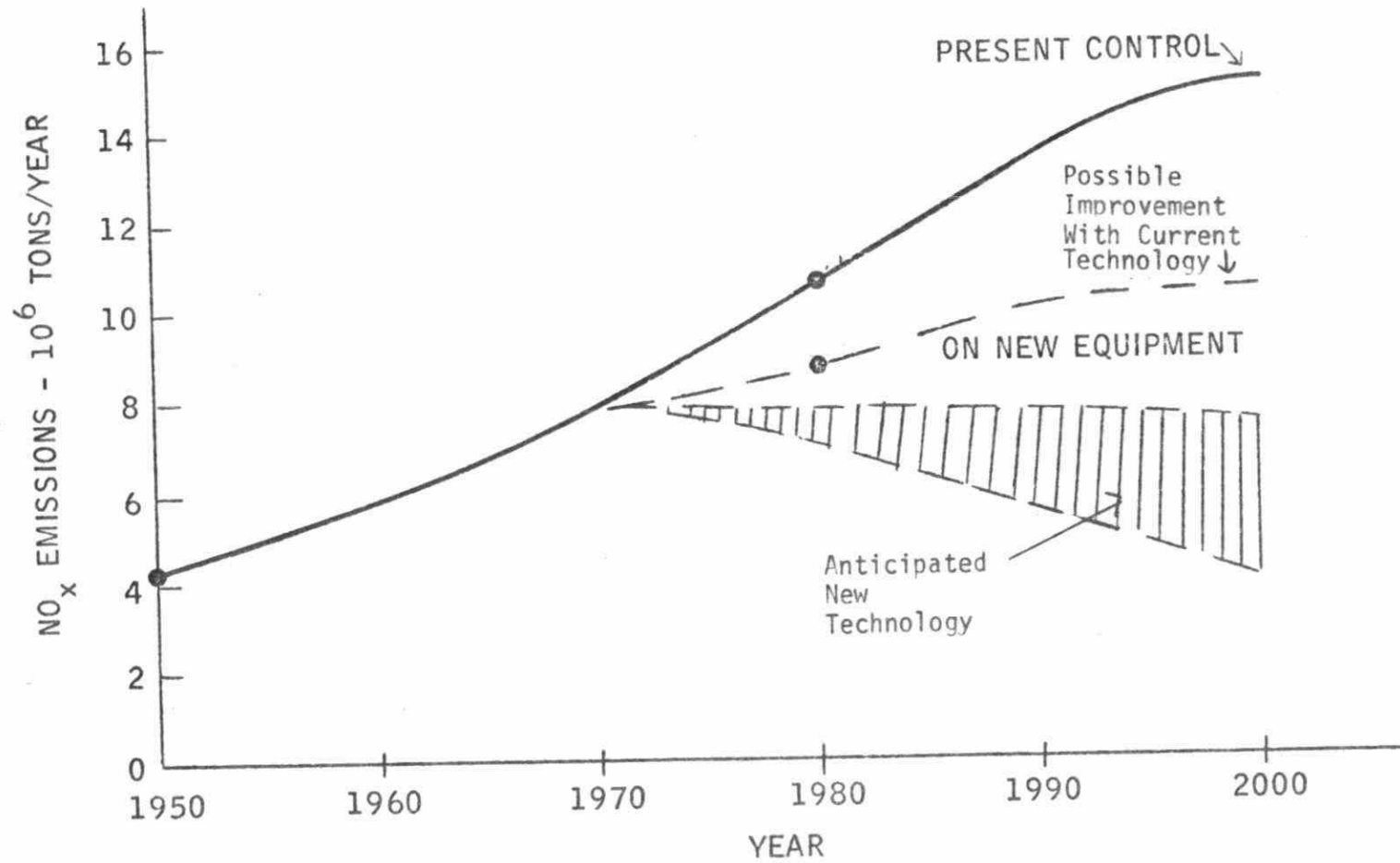
As is the case with  $\text{SO}_2$ , many control methods have been suggested, (a) fuel modification, (b) altering combustion techniques and (c) flue-gas treatment. Of these the second is currently receiving the most attention and Ontario Hydro has, on a pilot basis, reduced the present level of emissions by about a factor of 1/2 to 1/3. (43)

However, the  $\text{NO}_x$  control technology is not nearly as far developed as is that for  $\text{SO}_2$  and moreover, the problem may prove in the long run to be more complex. The future of  $\text{NO}_x$  abatement in the U.S. as viewed by the Esso study is depicted in Figure 10.

The curve labeled "possible improvement with current technology" indicates the best estimates of  $\text{NO}_x$  control to new equipment installed from 1970 to the years 1980 and 2000. Control methods in limited use at present, which have been effective for reducing  $\text{NO}_x$  emissions, include lower excess-

Figure 10

POTENTIAL CONTROLLED  $\text{NO}_x$  EMISSIONS -  
STATIONARY SOURCES  
IN THE U.S.



air combustion, staged combustion, flue-gas recirculation and changing burner location, spacing and configuration. The curve labeled "anticipated new technology" is based on wide use of potential combustion-control methods, such as steam or water injection and fluidized-bed combustion, combustion with oxygen in place of air, and flue-gas scrubbing.

The cost of  $\text{NO}_x$  abatement is still highly speculative. It is concluded, in reference 41, that in some cases operating costs will be lowered due to improved combustion. Present estimates indicate a cost of about \$1 to \$3 million a year for stations such as Hearn and Lakeview, and be comparable to the  $\text{SO}_2$  abatement costs.

- (iv) Heavy Metals - Heavy metals emissions into the atmosphere are possible because of the variety of impurities contained in fossil fuels as shown in Table IX. There is an increasing interest in "trace" or "exotic" pollutants in the atmosphere. These compounds may be extremely toxic, and low concentrations may damage flora or fauna, or become concentrated in the biosphere.

The measurement of these pollutants may be as difficult as the evaluation of their effects. Most of the compounds and elements are present

TABLE IX  
HEAVY METALS IN FOSSIL FUELS  
Coal Used by Ontario Hydro

Element	Quantity, ppm
Nickel	7 - 10
Manganese	0.1 - 0.3
Zinc	0 - 5
Chromium	0 - 10
Cobalt	0.5 - 1.0
Lead	0.5 - 1.0
Molybdenum	11 - 16
Vanadium	0 - 10
Beryllium	0 - 0.05
Arsenic	0 - 10
Antimony	5 - 10
Cadium	0.1 - 0.3
Silver	0 - 5
Selenium	1.0
Mercury	0.6

naturally in the environment, and the body can evidently dispose of certain levels of them. Research is now required to evaluate the effect, of continuous exposure of the population to low concentrations of trace metals, in order to determine which are present in undesirable concentrations.

Ontario Hydro has been concerned about the emissions of a number of materials from its plants.<sup>(52)</sup> The program undertaken includes a search for polynuclear hydrocarbons, especially benzo(a)pyrene -- and for fluoride, beryllium, selenium, nickel carbonyl, cadmium, antimony, bismuth and mercury -- in the coal, fly-ash and flue gas. Some of these substances may be carcinogenic. Because it is of great current interest, a detailed study of mercury emissions has been completed. It was found that 90 percent of the mercury in coal leaves with the flue gas with concentrations between 40 and 90 micrograms per cubic meter. At the present time, heavy-metal emissions from these plants are not regarded as a significant hazard and are within the Provincial regulations. The emissions from power plants cannot be distinguished from other sources. However, heavy-metal emissions are being closely monitored in Ontario.

(v) Other Emissions

Radioactive substances may also be emitted by fly-ash coming from fossil-fuel plants. A recent collection of data describing these emissions is given in Table X. These emissions are discussed later in connection with nuclear power plants.

Other emissions in the form of carbon monoxide and hydrocarbons also occur. All power generation companies strive to complete the combustion of unwanted CO and unburned hydrocarbons, in flue gases, by completing the reaction and forming CO<sub>2</sub> and water. However, all of the combustion processes we employ are, slowly but steadily, increasing the CO<sub>2</sub> content of our atmosphere. In the long-range, this could produce serious climatic alterations well into the next century as outlined later. If these fears materialize, we will have to turn to other methods rather than combustion to produce electrical power.

5.1.1.2 Control Methods of Fossil Fuel Plants Emission

Public utilities are in business to generate electricity, not to process chemicals. Nothing could be wanted less around a power plant than a complicated chemical process for cleaning flue gas that might go awry and force an outage. The utilities would much rather burn low-sulfur fuel to eliminate SO<sub>2</sub> and modify the burners to prevent

TABLE X

## Analyses of Radioactivity in coal and Oil Fly Ash

Sample	Refer- ence	Concentration (pCi/g dry fly ash)			
		Ra- 226	Ra- 228	Th- 228	Th- 232
Appalachian coal ash	(4)	3.8	2.4	2.6	---
Utah coal ash	(4)	1.3	0.8	1.0	---
Wyoming coal ash	(4)	---	1.3	1.6	---
Japan coal ash	(4)	---	1.5	1.6	---
Alabama coal ash	(4)	2.3	2.2	2.3	---
Venezuela petroleum ash	(4)	0.21	0.49	0.67	---
TVA coal plants	(3)	4.25	2.85	2.85	2.85
Coal ash (Australia)	(2)	7.98	---	---	---
Oil fly ash <sup>a</sup>					
Turkey Point	(5)	0.18	0.17	0.82	0.17
Coal fly ash <sup>b</sup>					
Hartsville	(5)	2.3	3.1	---	3.1
Coal fly ash <sup>c</sup>					
Colbert, TVA	(5)	3.1	6.9	1.6	6.9
Coal fly ash <sup>d</sup>					
Windows Creek, TVA	(5)	1.6	2.7	2.8	2.7

Data from reference 44.

formation of  $\text{NO}_x$ . However, some forms of chemical processing seems inevitable for coal- or oil-fired plants. From the information presented previously, it is clear that the abatement of air pollutant emissions from fossil-fuel plants will increase the cost of electrical power. Using consensus estimates it is believed that air pollution abatement programs only for fossil-fuel plants may increase costs in the following manner as more control is used and certain types of fuel become scarcer;

<u>Year</u>	<u>Price Index</u>	<u>Reason</u>
1972	1.0	-
1976	1.10	$\text{SO}_2$ Flue Gas Abatement
1981	1.15	Some $\text{NO}_x$ Abatement
1986	1.20	$\text{SO}_2$ , $\text{NO}_x$ , and Trace Metal Abatement
1991	1.20	-

Sulfur oxides (about 99%  $\text{SO}_2$  and 1%  $\text{SO}_3$ ) can be controlled through four basic approaches:

- (i) Dispersion from tall stacks.
- (ii) Substituting low-sulfur fuel.
- (iii) Removal of sulfur oxides from the flue gases.
- (iv) Desulfurizing existing fuel.

Each of these approaches also has several alternatives, and there is an abundance of literature attempting to shed light on this complex situation.

(i) Dispersion from Tall Stacks

The use of tall stacks and increased dispersions has been hotly debated in several countries over the past two or three years.<sup>(45)</sup> Although the Ontario regulations under the Environmental Protection Act permit dispersion from tall stacks as a means of controlling atmospheric sulfur dioxide concentrations, the government has made it clear that this is an interim measure and is only permitted when there are no practical means of controlling the pollutant at the source.

(ii) Substituting Low-Sulfur Fuel

As outlined previously, natural gas contains little sulfur, and power plants fired with gas contribute essentially no SO<sub>2</sub> to the atmosphere. However, the supply of natural gas is limited and with proven resources shrinking rapidly, the use of this premium fuel by public utilities should be restricted. Other low-sulfur fuels are in limited supply at least in areas where they are needed. Crude oils from Western Canada, North Africa, Nigeria and the Far East are naturally low in sulfur, and fuel oil produced from these crudes generally contain less than 1 percent of sulfur.

The reserves of solid fossil fuel with less than 1 percent of sulfur are ample. However, this huge

energy pool of sub-bituminous coal or lignite is found far from our consuming centers. Much of the remaining low-sulfur bituminous coal is reserved for metal production. About one-half of the total known U.S. reserves of bituminous coal average 2.2 percent sulfur.<sup>(46)</sup> These reserves, mostly located in the eastern or mid-western states, are the main source of energy for conversion to electricity.

Samples taken from the Onakawana lignite deposit indicate a sulfur content under 1%<sup>(14)</sup>; however, if this fuel is compared with existing coal supplies on an equal energy basis it contains an equivalent sulfur content of about 1.5%.

It must be concluded that direct substitution to low-sulfur fuel has little real potential over the time-span of this study. Its only practical application is in critical areas, for example, the recent conversion of Hearn Station.

(iii) Removing SO<sub>2</sub> from Flue Gases

Over the past 4 years great interest has developed in treating stack gases to eliminate SO<sub>2</sub> and more than 30 processes have been suggested. However, problems abound. The materials-handling problem alone is of a size seldom faced by engineers. A typical, large boiler furnace can send more than

50,000 tons of gas up the stack a day; even with  $\text{SO}_2$  making up only about 0.25 percent of it, this means that 125 tons of  $\text{SO}_2$  must be removed daily.

In considering the many different flue gas desulfurization processes, a distinction is made between recovery processes, in which a saleable by-product, such as sulfur or sulfuric acid, is produced, and a non-recovery process, in which a disposable waste product is produced. The market for saleable sulfur products, particularly in Canada, is unfavourable.<sup>(47)</sup> The large excess of sulfur on the world market has reduced the f.o.b. price of Canadian sulfur to between \$4 to \$10/ton. The domestic demand for sulfuric acid is easily met with acid produced from smelter operations. From an economic viewpoint, therefore, there is little incentive to develop and implement sulfur recovery processes.

The most advanced or promising processes under development are reviewed in references 47 and 48. In addition, the Ontario Research Foundation under contract to the Ministry of the Environment has made an independent evaluation of many  $\text{SO}_2$  removal methods. Table XI summarizes the ORF evaluation of flue gas desulfurization techniques

applicable to large power generation stations.<sup>(49)</sup>

Of all the processes in varying stages of development today, the limestone slurry process (Item 6, Table XI), is judged by Ontario Hydro and others<sup>(50)</sup> to have the best chance of early development. This is a throwaway process, in which the sulfur oxides in the flue gas are neutralized with limestone and converted to inert solids which can be disposed in a sanitary land-fill. Several variations of this process are under development in North America, but operational problems continue to occur. Ontario Hydro is studying this system on a 400-cfm pilot-plant scale and is investigating the feasibility of a larger unit. It is difficult to estimate the cost of any process that is not completely developed. Estimates made by Ontario Hydro differ significantly from those in Table XI made by ORF. Others<sup>(51,52)</sup> have estimated the operating costs of the limestone slurry process at between \$1 and \$4 per ton of coal. A figure of \$2 per ton presents the consensus opinion. Further, capital investment cost estimates ranges from about \$10 to \$40 per installed KW with about \$20/KW being typical. This control method could tentatively be planned for plants coming into operation late in this decade.

TABLE XI

## Approximate Costs of Flue Gas Desulphurization

<u>Process</u>	<u>Installed Capital Cost \$/KW</u>	<u>Total Operating Costs Including Capital Charges ¢/MM BTU *</u>
1. Pittsburg and Midway Solvent Refined Coal	?	16
2. Messman Chemical Coal Cleaning	?	6-7
3. IGT Coal Gasification	135	25.5
4. Garrett $K_2CO_3$ Process	13.5	7
5. Dry Limestone Injection	9	6
6. West Lime/Limestone Scrubbing	13	6
7. Stone and Webster Ionics	15	10
8. Chemico MgO Scrubbing	19	13
9. Monsanto Cat OX	32	16
10. Shell SFGD	26	16
11. Grillo AGS Process	?	12.5
12. Potassium Formate Process	15	7-8
13. Bischoff Process	?	15-19
14. Seawater Scrubbing	?	4

\* 1 ton bitum. coal ~ 25 MM BTU

The limestone slurry process produces a waste by-product of calcium sulphate and calcium sulfite. It is expected that 0.2 tons of waste by-product will be produced per ton of coal burned and treated. In the  $\text{SO}_2$  removal process, 60% will be in the form of solids which can be settled out and the remaining liquor can possibly be recirculated and reused within the system.

The settled solids may be left at the bottom of the lagoon or could be dredged out for removal to other disposal sites. These solids wastes are relatively insoluble and can be used in controlled landfill sites without too great a leachate problem. There is however, a possibility of a potential  $\text{H}_2\text{S}$  odour and appropriate measures would have to be taken to control this nuisance. If this system is adopted, then the planning aspect of coal-burning plants would have to take into account the land use requirement for disposal of this waste material from the desulfurizing of flue gases. There is a secondary type of recovery and treatment process available where  $\text{SO}_2$ , sulfuric acid, sulfur and fertilizer compounds can be recovered as by-products; however, the use of this process would depend to a large extent on the available markets for these various by-products. It is not expected that these methods will be employed before 1985.

Faintly visible on the horizon is a new method of burning fuels which will greatly reduce emissions, the fluidized-bed combustor.<sup>(53,54)</sup> It involves a stream of air moving slowly through a bed of inert material. Such a system can become a combustor if the bed material is heated to about 1500°F and a fuel, either oil or crushed coal, is admitted. If the bed material is limestone, the resulting lime will react with SO<sub>2</sub> as it evolves during combustion. Further, because the temperatures in fluidized system are uniform and can be held as low as 1500°F, little NO<sub>x</sub> forms. The fluid bed would also be useful in removing any trace heavy-metal elements which exist in coal. A recent special study in fluid-bed combustors has been carried out in Ontario by Bergougnou<sup>(53)</sup>. The fluidized boiler may be ideal for burning Northern Ontario lignites to produce power for gasification units at the mine-mouth. Such combustion would take place at relatively low temperatures of 1500 to 2000°F, to reduce the formation of nitrogen oxides. Similarly, a fluidized-bed boiler could burn city garbage. It would also be used to burn high-sulfur oil residues in case these are needed as a temporary supplement to fuel gas. Existing pulverized-coal furnaces could be adapted

to a low-pressure fluidized-bed combustion. A possible scheme could be to build a satellite fluidized-bed boiler close to the existing power plant. Limestone would be injected into the bed to retain the sulfur in the ash. The rest of the air would be mixed with the gas coming out of the fluidized-bed boiler for firing in the existing boiler. Another possibility would be to build a LURGI gasifier and to use the low-BTU gas produced to fire the existing furnace.

Bergougnou indicated that power plants using fluidized beds burning solid fuel could be constructed about 1980 if a research and development program, beginning in 1972 is emphasized.

(iv) Desulfurizing Fuels

On the average, half of the sulfur in coal is present as pyrites (iron sulfides) and half is combined chemically with the complex coal structure. Depending on the size of the pyrite particles, they can be removed. None of the organic sulfur can be removed without destroying the coal's molecular structure, e.g., by converting it into a fuel gas. Hence, about half the sulfur can be taken from coal by cleaning and at costs, for example, ranging upward to \$1 per ton, adding some 15 to 30 percent to the fuel costs.<sup>(55)</sup>

At the present time, the emphasis has turned on coal gasification as the best long-range approach to clean fossil fuel in large amounts. Coal gasification consists of the chemical transformation of solid coal into pipeline quality gas. This gas, primarily composed of methane, is virtually sulfur free and has a heating value of about 1000 BTU/ft<sup>3</sup>. The United States has undertaken a major development program in coal gasification<sup>(56)</sup> by the methods listed in Table XII.

Bergougnou has also carried out an investigation of the environmental impact of coal gasification in connection with the possible development of the Onakawana lignite deposits. Although there are several potential air-and water-quality problems, the main environmental impact would come from the water evaporated from the lignite, which comes to the plant with slightly more than 50% water content. This water evolved by gasification is approximately equivalent to a daily rainfall of 1.3 inches over an area of two square miles. Severe local icing and fogging might result in winter. However, mechanical de-watering could considerably alleviate this problem. The sulfur produced would amount to 2260 tons per day, which would represent a serious stockpiling problem in

TABLE XII

## US Coal Gasification Process

Process	Laboratory	Sponsor	Federal Funding FY 1972
HYGAS (Electrotherma)	IGT	OCR-AGA	\$3,500,000
HYGAS (Oxygen)	IGT	AGA	
CSG (CO <sub>2</sub> Acceptor)	Consolidation Coal Co.	OCR	3,420,000
SYNTHANE	BuMines	BuMines	1,500,000
BI-GAS	BCR	OCR-NCA	3,300,000
STEAM-IRON	IGT	Industrial	
FIXED BED	BuMines	BuMines	750,000
FIXED BED	Lurgi	Lurgi	

the absence of markets. Dust entrained in flue gas leaving the lignite dryer would amount to about 15 pounds/minute if the dryers were equipped with two stages of cyclones and an electrostatic precipitator.

The combined use of lignite gasification and fluidized-bed boilers appears very attractive for Ontario energy needs in the near future. Environmental deterioration would be smaller compared to present power schemes. An ecological study should be initiated for the lignite fields of Northern Ontario to determine, in detail, the impact of gasification on the local environment. Additional details of the pollution aspects of lignite gasification as well as the environmental problems of burning it in a mine-site power plant are given in reference 53. Fuel is more amenable than coal to desulfurizing: generally, the oil is treated with hydrogen to form hydrogen sulfide gas, which then can be separated and converted to elemental sulfur. Hydrodesulfurization has been developed actively over the past few years, but the cost is still high. Desulfurizing fuel oil to acceptable levels of about 1% sulfur costs from 50 cents to \$1 per barrel.<sup>(57)</sup>

Table XIII summarizes the fixed and operating costs of various sulfur abatement alternatives and their effect on the cost of electrical power production. This comparison is shown together with an estimate of the degree of sulfur removal and when the technique may be employed.

It is difficult to compare the cost of  $\text{SO}_2$  abatement with the indirect cost of no abatement, because there is no way to firmly establish the cost of the latter. The U.S. Environmental Protection Agency estimates that emitted  $\text{SO}_2$  indirectly costs the public 10¢ per pound. This figure is debatable, but the EPA has proposed a  $\text{SO}_2$  emission tax increasing from 5¢ per pound in 1972 to 20¢ per lb emitted  $\text{SO}_2$  after 1974.<sup>(58)</sup> As shown in Table XIV such a tax may be as high as several times the cost of abatement.

#### 5.1.1.3

##### Emissions by Nuclear Fuel Plants

In normal day-to-day operations, nuclear power plants are permitted by law to release radioactive substances to the environment in gaseous, solid and liquid forms. The standards applicable to the operation of a nuclear station for effluent releases from the station are radiation dose standards set by the Atomic Energy Control Board, based on the recommendations of the International Commission in Radiological Protection.

Tab. XIII - Cost Estimates of Electrical Power Production From  
Various Primary Energy Sources for Southern Ontario

Cost (mills/KWH)	COAL*						OIL*		GAS *	NUCLEAR**	ADDITIONAL COST FOR FLUE GAS DESULFURIZATION
	2.5% S base	1% S	Gasified Bitum.	Lignite	Cleaned Mechanical	Chemical	2% S	Desulfuri- zed to 1%			
Capital	2.39	2.39			2.39	2.39				4.60	
Operating & Maintenance	0.44	0.44	2.35	2.35	0.44	0.44	2.53	2.53	2.35	0.80	6-20¢ per MM BTU FUEL REQUIREMENT
Fuel Cost at Generator	4.25	5.10	9.00	9.00	4.95	5.65	5.40	6.22	5.35	0.97	
Reduction of Sulfur Emission (%) (base 2.5% coal)	(0)	(60)		(75)	(40-60)	(60)	(20)	(60)	(100)	(100)	(55-85)
Total Cost (mills/KWH)	7.08	7.93	11.35	11.35	7.78	8.48	7.93	8.75	7.70	6.37	0.6 - 1.7
Approx. Availability	now		1985		now	pilot scale	now	now	now	now	now, but perfor- mance not as yet known

\* Assuming 60% load factor and 40% fuel conversion efficiency.

\*\* Assuming 90% load factor and 28% fuel conversion efficiency.

T A B L E   X I V

COST BENEFIT ESTIMATE OF SO<sub>2</sub> ABATEMENT OF A HYPOTHETICAL  
1000 MW THERMAL POWER PLANT\*

	Cost MM\$/Year	Cost Mills per KWH	Cost per MM BTU (¢)
Approx. Cost of Flue Gas Desulfurization (90% Reduction SO <sub>2</sub> Emission)	2.6 - 8.0	0.6 - 1.7	6 - 18
Use of 1% of Sulfur Coal	4.5	1.1	10
Cost of a Hypothetical Tax on SO <sub>2</sub> Emission (90% Taxed at \$0.05/lb SO <sub>2</sub> )	7.7	1.8	17
Estimated Damage of SO <sub>2</sub> Emission \$0.10/lb SO <sub>2</sub> according to EPA**	17.0	4.0	39

\* Assuming a coal-fired plant and coal contg. 2.5% sulfur.  
Annual SO<sub>2</sub> emissions ~ 85,000 tons.

\*\* Costs to health, materials, property and vegetation (US - nationwide)

As a matter of interest some common risks normally encountered at present are compared to those presently associated with the generation of nuclear power below.<sup>(59)</sup>

(1) Death by Auto Accident	1 in	5,000
(2) Occupational Death	1 in	10,000
(3) Death by Commercial Airplane Crash	1 in	100,000
(4) Death or Handicap by X-ray Diagnostic Dose	1 in	200,000
(5) Death or Handicap by Nuclear Plant Radiation	1 in	200,000

A certain amount of radioactive material is released routinely in the operation of a CANDU-type (Canadian Deuterium Uranium) power station both via the ventilation system and via the condenser cooling water. An extensive effort is made to minimize the release of primary coolant and moderator since it is heavy water and valuable. Other radioactive releases are controlled, but an extensive effort is not made to reduce these to the absolute minimum. The primary released quantities are summarized below. Generally, they are only a fraction of the Derive Release Limit (DRL).

<u>Gaseous Effluents</u>	<u>Permissible daily releases (averaged over one year) Ci/day</u>	<u>Actual daily releases (averaged over one year) Ci/day</u> *
Tritium (oxide)	$4 \times 10^{-2}$	$5.7 \times 10^{-4}$
Iodine - 131	$7 \times 10^3$	30
Noble gases	$5 \times 10^3$	$4.4 \times 10^2$

Tritium is an activation product produced in the reactor by neutron bombardment of heavy-water moderator. It has a half-life of 12.5 years and represents a possible long-term hazard due to build-up in the biosphere. Studies indicate that, even in an expanded power industry, in the year 2000 the annual increase in background dose due to tritium will be less than 0.001% of natural background dose.<sup>(60)</sup>

Iodine-131 is a fission product and only appears if a defect occurs in a fuel bundle. Fuel defects have been occurring in CANDU reactors and small quantities of Iodine-131 have been released on occasions, but again, only a small fraction of DRL. Future improved fuel performance and ventilation system design are expected to reduce this even further. Exposure pathways for iodine are by inhalation and through foods (primarily milk).

\*Values supplied by Ontario Hydro for the (200 MW) Douglas Point Prototype Station, which is a comparatively small station by present-day standards.

The radioactive noble gases may be fission products or activation products. The fission products are isotopes of Argon, Krypton and Xenon. Noble gases have so far been the major radionuclide group released and in some years have averaged 10% of the DRL. Improvement in fuel design and delay storage systems will help control emissions from future large multi-unit stations.

The amounts of radioactivity found in the environment as a result of present-day reactor operations are indistinguishable from those due to natural background and fallout from nuclear-weapon testing. Radiation caused by nuclear power stations can be kept well within the limits imposed by current radiation protection standards, but the question has been raised if this will be possible as more nuclear plants come into existence, or if allowable limits are reduced.

The principal types of nuclear power plants presently in operation in the U.S.<sup>(56)</sup> are of a different type than the CANDU, and are also being considered by Ontario Hydro as possibilities in their planning. They utilize light water in the pressurized-water reactor (PWR) or a boiling-water reactor (BWR). Radiation exposure at the site boundary of the American systems are presently restricted to 0.005 rem/year, however, actual exposures are estimated to be considerably less than this. The Americans are beginning to design plants with reduced emission levels. It is impossible

to make a simple comparison of the effects of effluents from nuclear and fossil-fuel plants. Gas emissions from nuclear plants produce 'whole-body' exposure whereas radionuclides in fly-ash represent hazards to specific parts of the body. If the fly-ash is insoluble it lingers in the lungs; if it is soluble it passes into the blood and settles in the bone tissue. Some investigators have attempted to compare these emissions as fractions of total dose limits allowed by the International Commission on Radiological Protection (ICRP Dose Limit)<sup>(62)</sup> The CANDU and American nuclear systems are compared to a coal-fired plant in Table XV. This rough comparison illustrates that, from an air quality viewpoint, nuclear plants and coal-burning plants represent about the same hazard of airborne radioactive substances.

#### 5.1.2 Water Pollution

##### 5.1.2.1 Fossil-Fuel Plants

The release of conventional (i.e. non-radioactive) wastes from thermal generating stations does not currently present serious water quality problems nor are such problems expected to arise within the next twenty years provided that provincial waste discharge regulations are complied with. Effluents, such as spent boiler clean-out solutions, water-treatment wastes and coal-pile drainage, are easily treatable at relatively low cost, utilizing existing technology.

Discharges originating from wet ash-disposal systems however,

Table XV

Comparing Radioactive Gas Discharges from Fossil and Nuclear Central Stations

<u>Parameter</u>	<u>Coal plant</u>	<u>Pressurized- water reactor</u>	<u>Boiling-water reactor</u>	<u>CANDU* heavy water</u>
Size, MW	1000	462	200	340
Stack discharge				
Fly-ash, gm/yr	$1.5 \times 10^9$	-	--	-
Radioactive radium and thorium isotopes, mCi/yr	14.1**	-	-	-
Noble gases, Ci/yr	-	3.7	240,000	161,000
Liquid discharge				
Fission products, Ci/yr	-	3.8	6.0	-
Tritium, Ci/yr	-	1735	2.9	30
Dose limit (ICRP), micro-rem/hr	110	57	57	30
Dose limit per MW micro-rem/hr	0.11	0.12	0.29	0.09

\* Douglas Point

\*\* 99.5% Fly-ash removal

may result in the release of unacceptable quantities of ash or dissolved solids to the aquatic environment, unless the disposal systems are designed to minimize such releases. Fly-ash is generally disposed of by dry transport, which poses no water pollution problems. At the Nanticoke plant however, a wet fly-ash handling system is being installed. Since a greater percentage of soluble material is present in fly-ash than in bottom ash (i.e. boiler slag), the transport water will contain unacceptable quantities of dissolved solids. Consequently, it is planned that the slurry water will be recirculated through a lagoon and re-used rather than discharged directly to the lake. However, there is a greater input of water to the lagoon than is re-used. As a result, a discharge to the watercourse of about 440 gpm is expected. The extent to which dissolved solids will build up in the lagoon waters is unknown. It is expected however, that the water will be saturated with the various salts leached from the fly-ash and the discharge of dissolved solids to the lake could conceivably exceed 25 tons per day per 1000 MW. It must be therefore concluded, that the only suitable method of fly-ash disposal for future plants is by means of dry transport or by a completely closed recirculation system. The technology for such a system is available.

#### 5.1.2.2 Radioactive Releases

The release of radioactive wastes to the aquatic environment is regulated and limited by the Atomic Energy Control Board. At the present time, the release limits are based upon the radiation dose limits for individual members of the public. They have been converted to concentrations of the various radionuclides in water, which will not provide an unacceptable radiation dose for a hypothetical group of individuals who might be drinking the effluent from the station and consuming fish that have grown in the effluent channel.

Experience with several reactors in Canada has shown that the actual release of radioactive wastes is only a fraction of the allowable releases, based on concentration criteria. This is due largely to the fact that concentrations are measured in the outfall, and reactor operation requires large quantities of water for cooling purposes. Using these vast quantities of cooling water as a sink for the disposal of active wastes has enabled the industry to largely avoid treatment of such wastes for removal of the radioactive constituents.

A typical CANDU nuclear generating station operating with a once-through cooling water system requires about 800,000 U.S. gpm of water per 1000 MW of generating capacity. Based on the approximate average flow rate of the St. Lawrence of  $9.3 \times 10^7$  gpm about 117,000 MW of nuclear capacity will utilize the equivalent quantity of water

flowing through the Great Lakes system.

If all of these future nuclear plants were to release the quantities of radioactive waste allowed by existing AECB requirements, the water and fish within the Great Lakes might eventually contain radioactivity to the extent that the maximum permissible radiation dose levels would probably be received by a significant segment of the population of the Great Lakes areas. Recently, the Atomic Energy Commission in the U.S. reduced the allowable releases of radioactivity from certain types of reactors by a factor of about 100, thereby bringing actual and allowable releases more in line with each other. The AECB is also currently considering the establishment of maximum permissible release criteria which will more closely approximate the actual releases from Canadian reactors. What is not known at this time is whether the new AECB requirements will, when implemented, require reactor owners to treat the active liquid wastes prior to discharge.

A comparison of allowable and actual releases of radioactivity from nuclear power plants shows that such releases can be held far below the quantities allowed under current standards. Such releases, however, could be still further reduced, sharply in some cases, by the application of proven economical waste-control measures.

To quote from reference 63: -

"The issue involved is whether the nuclear industry should possess the right to pollute the

environment or to expose members of the public to hazardous materials to a needless extent. If the nuclear power industry does, in fact, have such a right, then all other industries will insist on a similar right with respect to other contaminants. The solution is to require all industries, including nuclear power plants, to reduce and minimize all releases of contaminants to the full extent that is both technologically feasible and economically reasonable."

To quote the International Commission on Radiation Protection (ICRP),

"The maximum permissible doses recommended... values; the commission recommends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided." The U.S. Federal Radiation Council has stated that the case as follows" "There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It is basic that exposure to radiation should result from a real determination of its necessity."

From such admonitions, a policy of actively minimizing all human radiation exposure is clearly required of

any responsible regulatory agency.

The question of how much radioactivity should be released to the aquatic environment for operations connected with the production of power is highly contentious. The necessity of balancing risk and benefits is obvious, but subject to great uncertainty. In view of the growing consumption of energy and the existence of other environmental forces directing us toward the installation of greater nuclear power capacity, and to ensure that the build up of radioactivity in the environment should not become an undesirable burden on future generations, it is recommended that the following policies be adopted;

- (1) Radioactivity in the aquatic and atmospheric environments attributable to controlled releases from all operations should be kept to the lowest practicable level.
- (2) The total burden of radioactivity in the water, sediments, and biota of the Great Lakes should not be allowed to increase by the discharges of radioactivity from nuclear operations.

#### 5.1.2.3 Thermal Discharge

Electrical power generation plants, whether nuclear or fossil fueled, have an energy conversion efficiency of

between 30 and 40 percent. The fossil plants discharge a small part of their waste heat into the air, while all the waste heat from nuclear plants goes into the water.

The use of water for cooling purposes is a common practice in many industrial operations, and particularly important in the generation of electricity. Although thermal waste is common to both nuclear and fossil-fuel plants, nuclear plants produce substantially more waste heat per unit of electricity generated. Energy-conversion efficiencies for existing plants and some possible future improvements are listed below:

<u>Type of Plant</u>	<u>Portion of Energy Converted to Electrical Power</u>
Fossil fuel plant	38 to 40%
Proposed fossil plants with MHD topping cycle	53 to 59%
Present heavy and light water nuclear reactor plants	30 to 32%
Proposed advanced nuclear reactor plants	39 to 43%

The electrical-power industry has a strong economic motivation to improve these conversion efficiencies and reduce the amount of waste heat discharged. The prospects of a significant improvement beyond the limits shown above by the end of the century are rather dim.

The present controversy on thermal 'pollution' has arisen because of the phenomenal growth of the electrical-power

industry, particularly in the United States, where many power stations have been built on relatively small lakes and rivers, and have sometimes caused significant ecological changes in the aquatic environment.

Predicting the effects of waste heat on the aquatic environment is only in the initial development stage. Since temperature is considered to be the primary control of life on earth, it is therefore important in a body of water. Because the surrounding temperature can determine the species that will live and reproduce, ecologists are deeply concerned with the threat to fish and other aquatic life forms which can occur in the future, because of increases in power demands.

One or more of the following effects may be induced by thermal discharges<sup>(64)</sup>. As water temperature rises in a river or lake, dissolved oxygen levels may decrease - a biologically important factor.

Decomposition of organic (sewage) waste is accelerated by elevated temperatures, thereby further reducing dissolved oxygen levels necessary for the maintenance of a healthy habitat. There is a decrease in spawning success and in the survival of young fish. Normal biological rhythms and migration patterns are confused. Prey-predatory relationships are disrupted. Oxygen concentrations are decreased at the very time when more

oxygen is needed by the aquatic life because of the increase in temperature. Not only is the temperature of the water increased, but there are apt to be sudden changes in temperature, for example, due to shut-downs of the plant. It is therefore difficult for a new web of species, adapted to the warmed temperature, to become established<sup>(65)</sup>.

Apart from other factors such as light and nutrients, heat may also stimulate algae growth. This is important from the aspects of water supply and recreation. Massive growths of algae increase water treatment costs. Also, if certain types of algae predominate, taste and odour problems can be experienced with the water supply. There can also be beneficial effects of heat inputs to watercourses. In winter, heated water may prevent ice formation and promote navigation in water passages normally blocked, although the economic advantages of this seems questionable at present. Growing seasons can be extended and rates of growth increased for fish in their natural environment and in fish farms because of higher water temperatures. Swimming areas could be provided in certain cold-water lakes, thus increasing the recreational potential of those lakes. However, summertime algae growth may discourage swimmers and boaters. Utilizing the kinetic energy of the cooling water to induce local water-circulation may prove to be beneficial in improving local water quality. The

Hearn plant cooling-water system is considered to enhance the water quality in the Toronto inner harbour by inducing a continuous circulation within the harbour.

Although thermal discharges are not known to be a serious problem in Ontario at this time, available information is inadequate and extensive studies are being undertaken on this matter, particularly with respect to the long-term effects. Further, the thermal characteristics and water quality of the Great Lakes differs significantly not only from lake to lake but at different locations on a given lake.

Recent studies sponsored by the Federal Government<sup>(66)</sup> have indicated that waste-heat inputs to the Great Lakes are expected to increase substantially in the period between 1970 and 2000. As an indication of the magnitude of the thermal input, the total man-made input to Lake Ontario for one year in the year 2000 A.D. is 6 percent of the existing annual natural heat content variation within the lake.

Increases in average surface temperature (considering the whole lake) by the year 2000 are unlikely to have any dramatic effect on the ecology of Lake Ontario.

Local temperature increases in the area of the discharge, however, may be significant. The thermal plume from the Lakeview generation station, for example,

is detectable at distances greater than one mile from the discharge point on occasions (see Figures 11 and 12). Near-shore dynamics are such that one would expect the thermal plume to be detectable in excess of one mile radius from the discharge point for a cooling-water discharge of approximately 2000 cfs at 16<sup>0</sup>F above lake water temperature. (Proposed plants will discharge in excess of 10,000 cfs at similar temperatures.) It is now possible to estimate the physical extent of thermal plumes on lakes (67 to 71) and rivers (72). However, the long-term chemical, biological and modification of the local fishery effects are not known, but are under study. Lake Erie is a special problem. It has been despoiled by a wide variety of man's waste, predominately from the U.S. shore. Reference 66 states, that Erie will be receiving the same man-made heat input per unit surface areas as Lake Ontario between now and the year 2000. Because it is considerably shallower, its overall temperature increase and localized water temperatures may be much greater than those for Lake Ontario and it is expected that local fishery and biological activity will be affected. Some areas are much more sensitive to thermal discharges than others. In particular, regions where high levels of algae presently exist should be avoided (e.g. western and central basins of Lake Erie, etc.). Thermal

Flow 2140 cfs at 60°F

WIND COMPONENT ALONG SHORELINE ( $W_p$ ) = 9.55 m.p.h.

RADIUS OF PLUME CENTERLINE (R) = 4,760 FT.

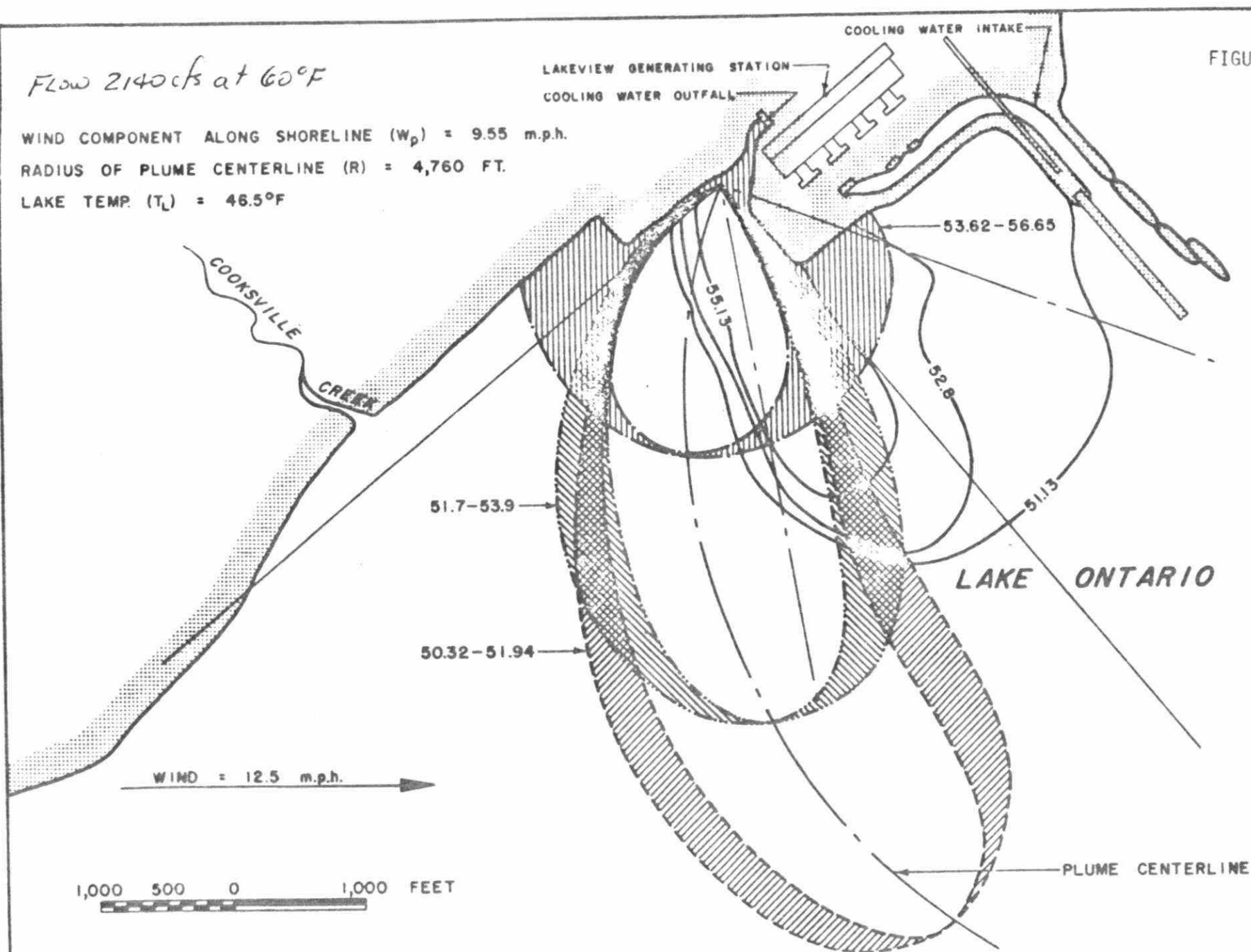
LAKE TEMP ( $T_L$ ) = 46.5°F

LAKEVIEW GENERATING STATION

COOLING WATER OUTFALL

COOLING WATER INTAKE

FIGURE 11



OBSERVED AND PREDICTED ISOOTHERMS (NOV. 13, 1969)

Flow 175 cfs at 84°F

WIND COMPONENT ALONG SHORELINE ( $W_p$ ) = 7.65 m.p.h.

RADIUS OF PLUME CENTERLINE (R) = 3,830 FT.

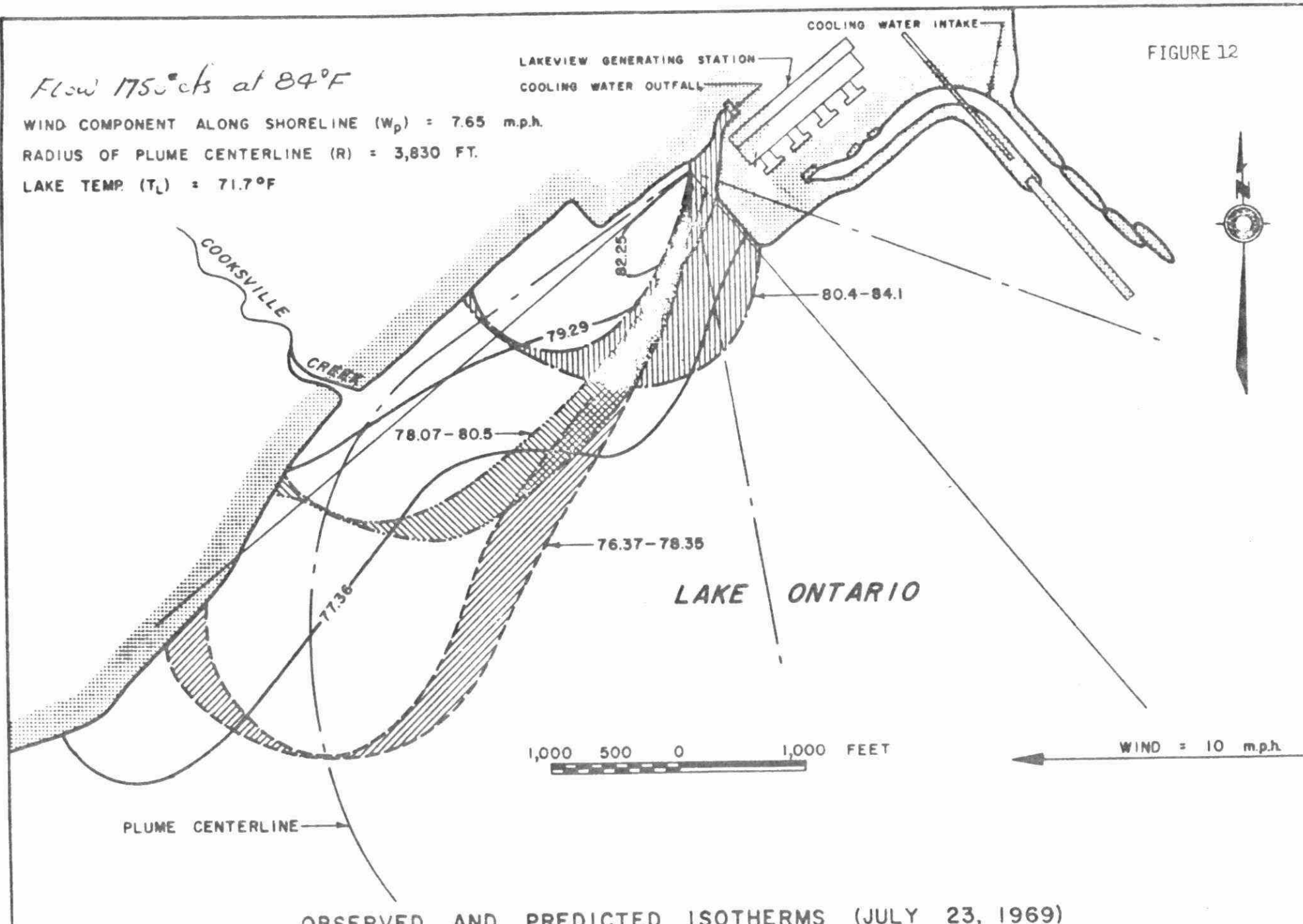
LAKE TEMP ( $T_L$ ) = 71.7°F

LAKEVIEW GENERATING STATION

COOLING WATER OUTFALL

COOLING WATER INTAKE

FIGURE 12



OBSERVED AND PREDICTED ISOTHERMS (JULY 23, 1969)

discharges should be avoided in known fish spawning grounds or in viable fishing regions.

Because the near-shore regions of the Great Lakes are highly variable in physical, chemical, and biological character and because many locations are unique, those organizations using the water for cooling should clearly demonstrate by appropriate studies that the discharge does not cause adverse effects at the discharge site.

In view of the unique features of Lake Erie and the possible overall rise in temperature over the next thirty years, Ontario Hydro has been advised by the Ministry of the Environment to consider the installation on cooling devices on any future thermal-electric-generating station on Lake Erie.

The joint Canada-U.S. agreement, which is currently in the final stages of preparation, will likely contain objectives for discharges of heat to the Great Lakes system. Finally, certain guidelines for governing thermal pollution of the Great Lakes and other waters of Ontario by electrical generating stations should be established:

- (1) In those instances where harmful effects can be predicted, alternate cooling facilities, which will not seriously impact the environment, should be employed.

- (2) In those instances where potential harmful effects may exist, but cannot be clearly predicted, power plants should be initially designed so that alternate cooling facilities can be added at such time as evidence indicates significant adverse effects.
- (3) Cooling-water discharges should not alter local existing circulation patterns such that other water users are seriously depreciated, or spawning and fishing grounds are effected.

#### 5.1.2.4 Control Methods of Thermal Pollution

The waste heat must be removed from steam electric-generating plants, but where should it be put? The most rational control method for thermal waste is to use the heat rather than releasing it to the environment. Yet very little work has been done, which might lead to practical present-day uses for this waste heat. A study of potential uses of waste heat in Ontario has recently been completed<sup>(73)</sup>.

It must be recognized that there are not many uses for waste heat of the low-rejection temperatures currently in use ( $50^{\circ}$  to  $85^{\circ}\text{F}$ ). To make the best use of the waste heat the power plants will have to operate less efficiently and reject its waste heat at temperatures of 200, 300 and possibly  $400^{\circ}\text{F}$ . Thus, the effective

utilization of waste heat would have to be preceded by a completely different operating philosophy. Some possible long-range alternatives are listed below:

- (1) Warm-water spraying or heating soil to extend growing seasons.
- (2) Heating and cooling of greenhouses.
- (3) Spray irrigation.
- (4) Snowmelting, outdoor heating and wintertime street and road clearing.
- (5) Fish Farming.
- (6) Area urban heating.
- (7) Waste heat and low-pressure steam for various industrial purposes.
- (8) Inducing better circulation in certain lake regions.

Presently, the most viable waste-heat disposal method is to put it into the air. If the air is used for heat dispersion, localized atmospheric heating could become a problem, particularly if the plant were located near centers of population<sup>(74)</sup>.

Various disposal methods are available, including direct, air-cooled condensers, cooling ponds and cooling towers. In addition, there are several types of cooling towers and several ways to operate the resulting system. Space does not permit a detailed

discussion, but Table XVI indicates some of the costs associated with various control measures for thermal wastes. Cooling ponds or lagoons require sizable land areas, up to one acre per MW of installed generation capacity.

Natural-draft cooling towers as seen in Figure 13 are presently the most popular alternative. In these "wet" towers, the heated water mixes with air and is cooled largely by evaporation, resulting in a substantial quantity of water being emitted to the atmosphere.

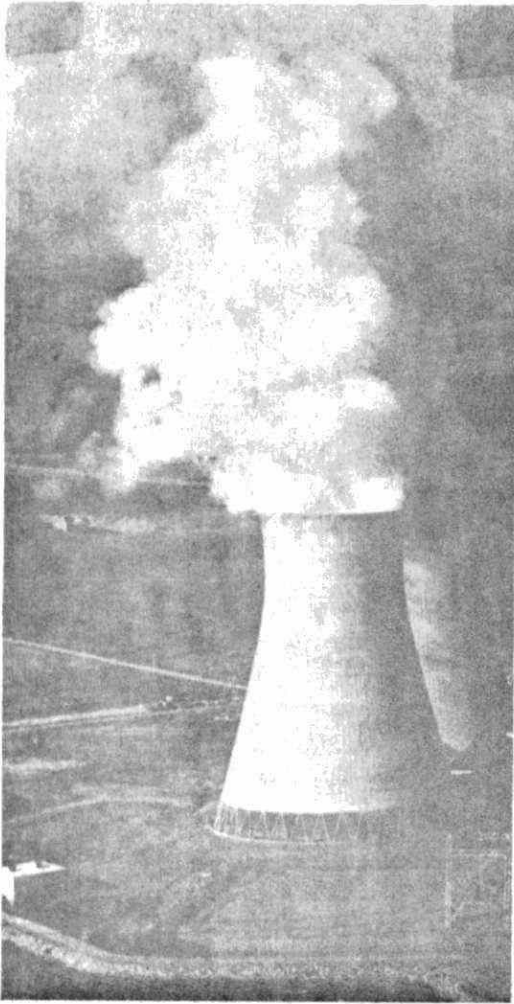
In Ontario, the environmental effect of giant-size cooling towers might be expected to be more significant than elsewhere because of lengthy periods of freezing weather during the winter time. Icing of the roads and reduced visibility, because of stable fog conditions caused by moist warm plumes hitting the ground, has caused concern and raised questions about the environmental impact of this cooling alternative.

Model tests have shown that aerodynamic flow disturbance behind the tower can, under certain wind conditions, produce a downwash causing the plume to touch down a few tower heights away and deposit water on the ground. A buffer zone of perhaps 1 mile, around evaporative cooling towers, could prevent a local reduction of visibility and ground icing on public property.

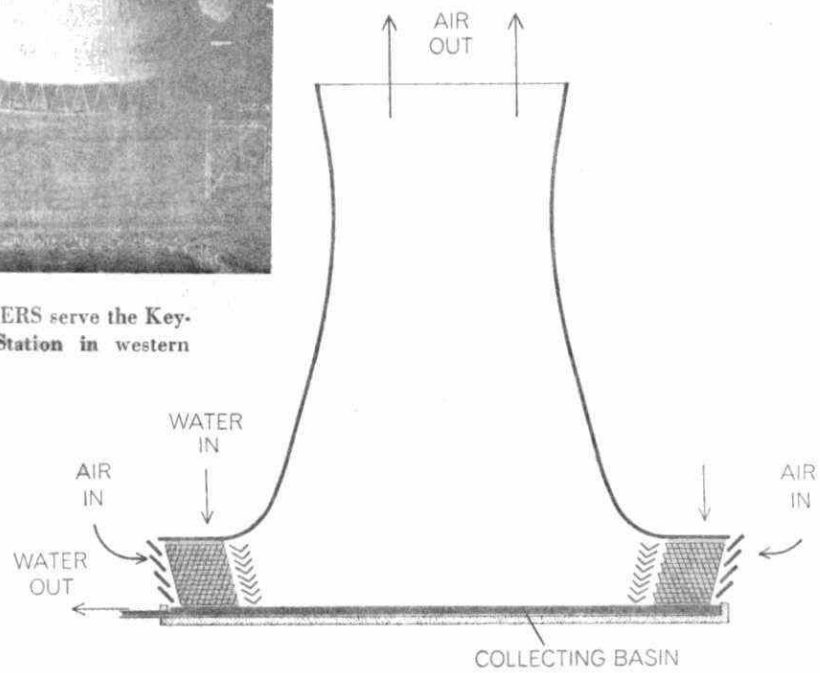
TABLE XVI

COMPARATIVE COSTS OF COOLING WATER SYSTEMS FOR STEAM ELECTRIC PLANTS			
<u>Type of System</u>	<u>Investment Cost for a 1,000 Megawatt Plant</u>		<u>Increase in Operating Costs Mills/kwh</u>
	<u>Fossil Fuel</u>	<u>Nuclear Fuel</u>	
Once-through, no control measures, heat discharged directly into a fresh water river or lake	This method taken as base-line--it is the minimum cost option and requires no additional costs		
Cooling ponds with recirculation of the water from the pond (approximately 1,000 acres needed for a plant of this size)	\$4 to 6 million	\$6 to 9 million	0
Wet cooling towers, most heat loss to atmosphere via evaporation with resultant production of fogs, mists, and considerable water loss	\$5 to 9 million	\$8 to 13 million	Forced 0.0771 Draft
			Natural Draft 0.0211
Dry cooling towers, heat transferred to atmosphere without evaporation, no resulting fog or mist. To date no such towers have been constructed for a large power station	perhaps \$20 million	perhaps \$25 million	0.0937

FIGURE 13



FOUR COOLING TOWERS serve the Keystone Steam Electric Station in western Pennsylvania.



Updated air-quality regulations forthcoming from the Ministry of the Environment will place an emission limit on water vapor such that a 30 minute average at the point of impingement for a receptor may not exceed 0.25 grams of water vapor per cubic meter. This limit is imposed to prevent fogging and/or icing from man-made vapor sources.

Although a preliminary analysis<sup>(75)</sup> indicates, that this cooling method will probably, in the next two decades, result in lower overall environmental impact than putting waste heat into water, more work in this area is needed. In particular, the flow characteristics of the plume in the wake of arrangements of several towers must be determined.

Also, it should be noted that when wet cooling towers are used for fossil-fuel plants, the  $\text{SO}_2$  emissions may interact with the water forming sulfuric acid mists. Obviously, such situations should be avoided.

"Dry" cooling towers which contain a closed-circuit, cooling-water systems, would resemble giant automotive radiators. They eliminate the problems of wet towers outlined above. The clear advantage of the

dry-type cooling tower, over all the other cooling devices, is its independence of large bodies of water. It would permit consideration of many more potentially attractive sites and would reduce the demand for highly valued land adjacent to water bodies. Its major disadvantages are its high cost as shown in Table XVI, and that to date no such towers have been constructed for a large power station.

#### 5.1.3 Impact on Land Use

- (i) Hydroelectric Power Generation - Dams and reservoirs affect water quality through thermal changes and interruption of the natural patterns of stream discharge.

The physical changes resulting from hydroelectric-power production affect fish production by preventing migration to spawning beds and causing fish kills. Spawning and nursery habitats are destroyed or changed. Waste entering the water from construction sites affect the chemical and physical properties of downstream habitat. New species of aquatic life can be introduced into receiving waters disrupting fish communities and introducing new diseases and parasites.

Stream regulation and diversion for the generation of power must be compatible with

existing downstream water uses, nor should flow regulation inhibit downstream development by denying the water resources to downstream users. In no instance should the river flow be reduced or fluctuate to such an extent that water-quality impairment exists downstream as a result of existing uses. This has occurred to some extent on the Madawaska River.

Low-water levels can limit recreational use, decrease shoreline property value and jeopardize aquatic biota. In addition, the fluctuating flow, combined with higher than normal peak flow rates during periods of maximum power generation, contributes greatly to increased erosion rates of the stream bed. The higher sediment loads carried by such streams impair the quality of water for potable use and consequently increase the costs of treatment.

It is also possible for diversion of flow through hydroelectric generators to decrease substantially the desirability of a waterfall as a tourist attraction. Niagara Falls, for example, is one case where the requirements of tourism have dictated that a minimum streamflow over the Falls be main-

tained. Kakabeka Falls on the Kaministiquia River near Thunder Bay has not fared as well. This Falls, once one of the finest natural attractions in the area, has been reduced to a fraction of its normal flow because of the diversion of the water for power generation.

Both in the operation of existing hydro generation plants and in the planning of new possible hydro-electric facilities, it is recommended that decisions affecting the following areas be carefully co-ordinated between cognizant government departments;

- (a) Effects of water-level fluctuations on flora and fauna, shoreline erosion, timber production, and recreational use upstream and downstream from dams.
- (b) Effects of dams, diversions, etc., on the aquatic environment.
- (c) Details of land clearing for impoundments.

(ii) Transmission Lines

Approximately 100 acres are required for one mile of transmission lines; the farther away an electric station is from the consumers of power, the more land is removed from other uses. Yet, the closer

a power plant is to consumers, the greater are the chances of harmful exposure of large numbers of people to the various pollutants produced by these plants.

Most of the environmental factors imply that the generation plant is best removed from population centers until the pollution abatement techniques discussed previously can be practically applied. Nevertheless, the aesthetic senses of increasing numbers of people are offended by transmission lines and by certain environmentally questionable practices in maintaining them.

Ontario Hydro appears committed to construct new rights-of-way in Southern Ontario in such a way that they will have a minimum impact on the surrounding topography. However, it is reported that separate (less strict) procedures will be issued for Northern Ontario. It is recommended that the policy adopted for Southern Ontario be extended to areas of Northern Ontario in the vicinity of present and possible future populated areas, and areas having present or future recreational and aesthetic values.

The use of herbicides and defoliants in clearing and maintaining transmission line rights-of-way has been questioned by several conservation groups and individuals in briefs to Task Force Hydro. An investigation

of this practice by the Ontario Pesticide Advisory Committee concluded that the current practices of Ontario Hydro, the type of herbicide used, the applied concentration and method should not lead to future difficulties<sup>(76)</sup>, and recommended that public groups be fully informed of the practices and invited to accompany the spraying teams. It should be noted that other types of ground-cover can be planned and used for weed control purposes. This approach should be encouraged.

(iii) Solid Waste Disposal

The disposal of ash waste materials, mostly from coal-burning plants presents little problem in terms of utilizing this material in controlled landfill sites. The product is relatively inert, poses little leachate problem, can be easily handled and spread on the site and when covered with approximately two feet of top soil and sodded, can be used almost immediately for limited recreational purposes.

Some preliminary research has been done using fly-ash as a filler material for road foundations and also as an aggregate for cinder-block construction and undoubtedly additional uses can be found for this product in the future.<sup>(77)</sup>

Radioactive waste disposal is regulated both at

the federal and provincial level. Originally, the policy of radioactive-waste disposal was to have all material buried in one controlled site on crown land so that control in perpetuity could be effected. Since the inception of radioactive-waste disposal, data collected with respect to on-site safety techniques, migration of radioactive products and general control of the site indicate now that other sites may be considered for this purpose.

Liquid radioactive wastes can be processed in a number of ways to reduce the amount of radiation to a point where secondary methods of disposal can be employed. Some of these methods would include;

- (a) chemical precipitation
- (b) ion exchange
- (c) absorption
- (d) dilution and discharge into sewers
- (e) deep-well disposal
- (f) combustion

It should be remembered however, that in each type of treatment, there will still be a solid-waste disposal problem associated due to the various by-products produced, process material and basic

equipment, which will wear out over a period of time.

At present, it is very difficult to quantify this aspect of waste material associated with energy production, until firm figures are available with regard to percentages of energy produced by nuclear sources as compared to others.

#### 5.1.4 Future Impact of Large Thermal Power Plants

The growth of electrical power demand and the current tendency of installation of power plants of increased capacity will undoubtedly continue in the next two decades and will result in the construction of more power plants in the size range of 4000 MW and above.

Air quality is not consistent across Ontario. There are large areas where air pollution is virtually non-existent. In areas with large populations and industrial development, air pollution is a serious problem. Ontario's cities are expected to grow considerably in size and population during the next two decades (Table XVII). This growth undoubtedly will also result in increased quantities of pollutants being emitted or discharged into the environment by a variety of sources. In the following the potential impact of a large hypothetical 6000 MW power plant will be examined and predictions of 1991 ambient air quality in three

TABLE XVII

## POPULATION FORECAST FOR ONTARIO

	1971	1991	Per Cent Increase
Ontario	7,582,000	10,321,000	36%
Toronto	2,436,000	3,596,000	48%
Hamilton	492,700	742,600	51%
Sudbury	130,500	191,800	47%
Sarnia	70,510	110,500	48%
Windsor	232,300	328,300	41%
London	230,700	328,600	42%

Data from reference 79.

different regions will be made by adding the emissions of a 6000 MW fossil-fuel plant to the projected emissions from other sources assuming a 75%  $\text{SO}_2$  removal for power stations.

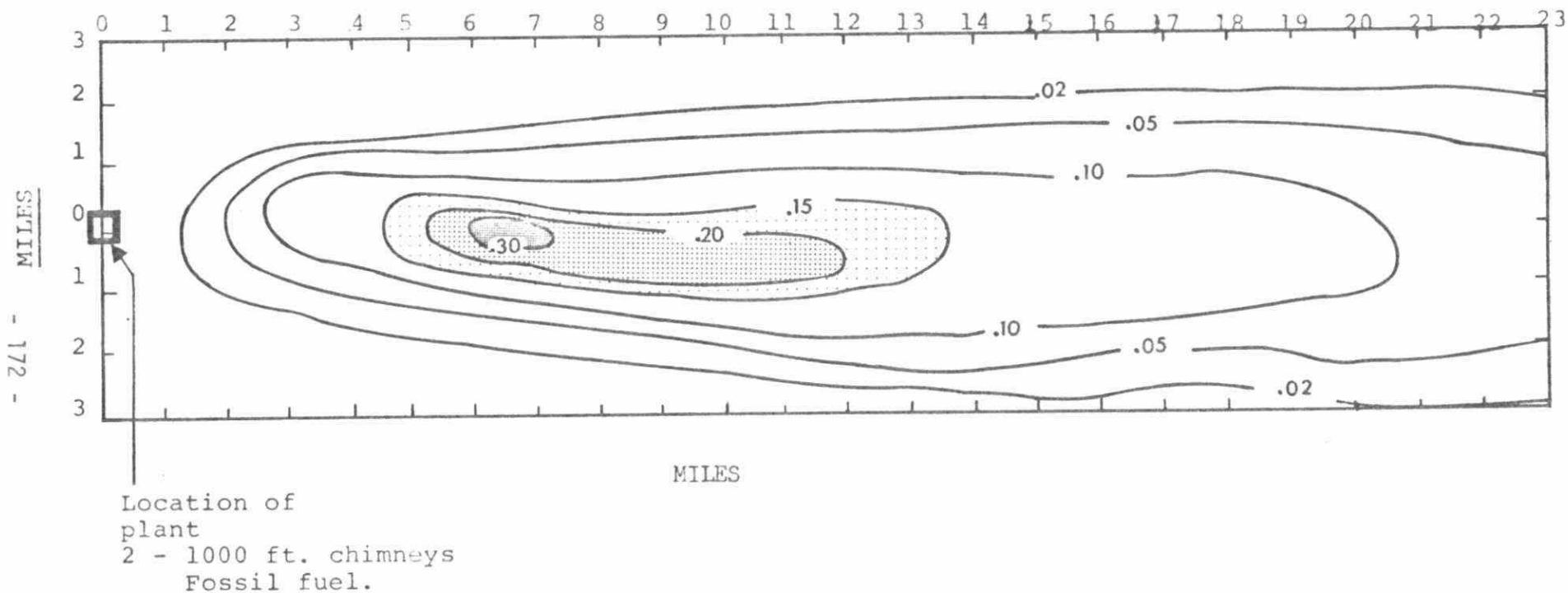
#### 5.1.4.1 Air Quality

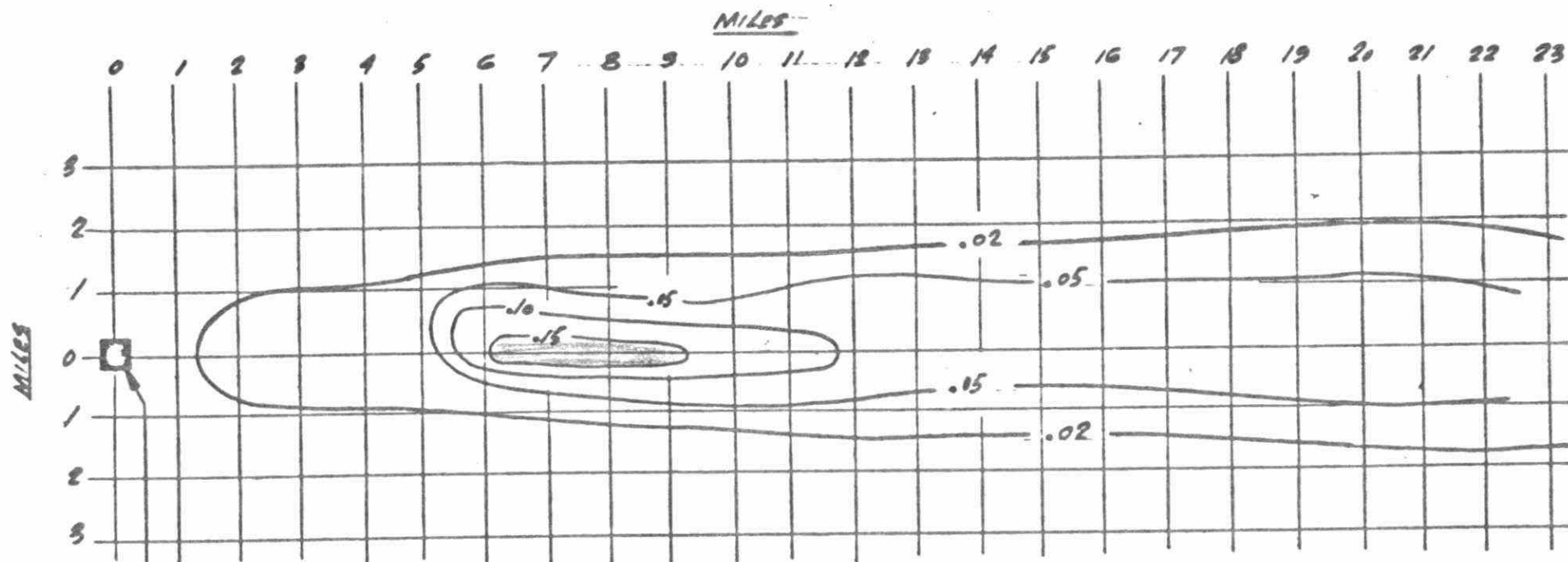
Calculated ground-level concentrations of  $\text{SO}_2$ ,  $\text{NO}_x$  and solid particles, downwind from a hypothetical 6000 MW coal-fired plant, are shown in Figures 14 to 16. These calculations were made to illustrate the potential impact of plants of this size on the environment.<sup>(78)</sup> Calculations were made for 1000 ft high stacks, 2.5% sulfur coal and typical weather conditions. The predicted ambient  $\text{SO}_2$  concentrations (Figure 14) without a removal process, exceed the Regulations between 5 and 12 miles, with a 75% efficient  $\text{SO}_2$  removal process in operation, the ambient-air criteria are exceeded for a short distance around 6.5 miles from the station (Figure 17). Both  $\text{NO}_x$  and particulates do not exceed their maximum permissible concentration at the point of impingement, but the expected  $\text{NO}_x$  concentration leaves little margin for additional  $\text{NO}_x$  emission from other sources.

##### (i) Rural Location

Figure 18 shows the  $\text{SO}_2$  ground-level concentrations in a typical rural area for a hypothetical lake-

Fig. 14 Predicted Downwind Concentrations  $\text{SO}_2$  for a hypothetical 6,000 Megawatt Power Station (Hourly Average p.p.m.)



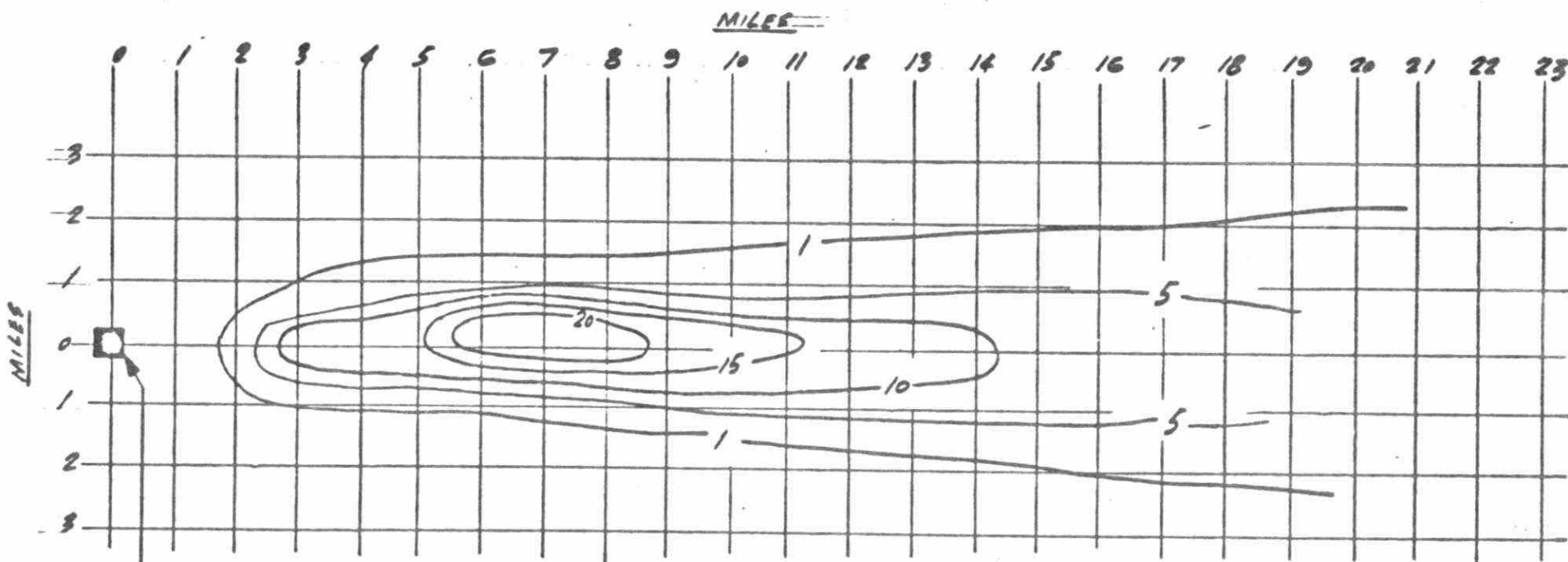


LOCATION  
OF PLANT.

PREDICTED DOWNWIND CONCENTRATIONS NO<sub>x</sub>  
HOURLY AVERAGE P.P.M.

6,000 MEGAWATT POWER STATION  
2 - 1000 FT. CHIMNEYS  
FISSILE FUEL.

FIGURE 15



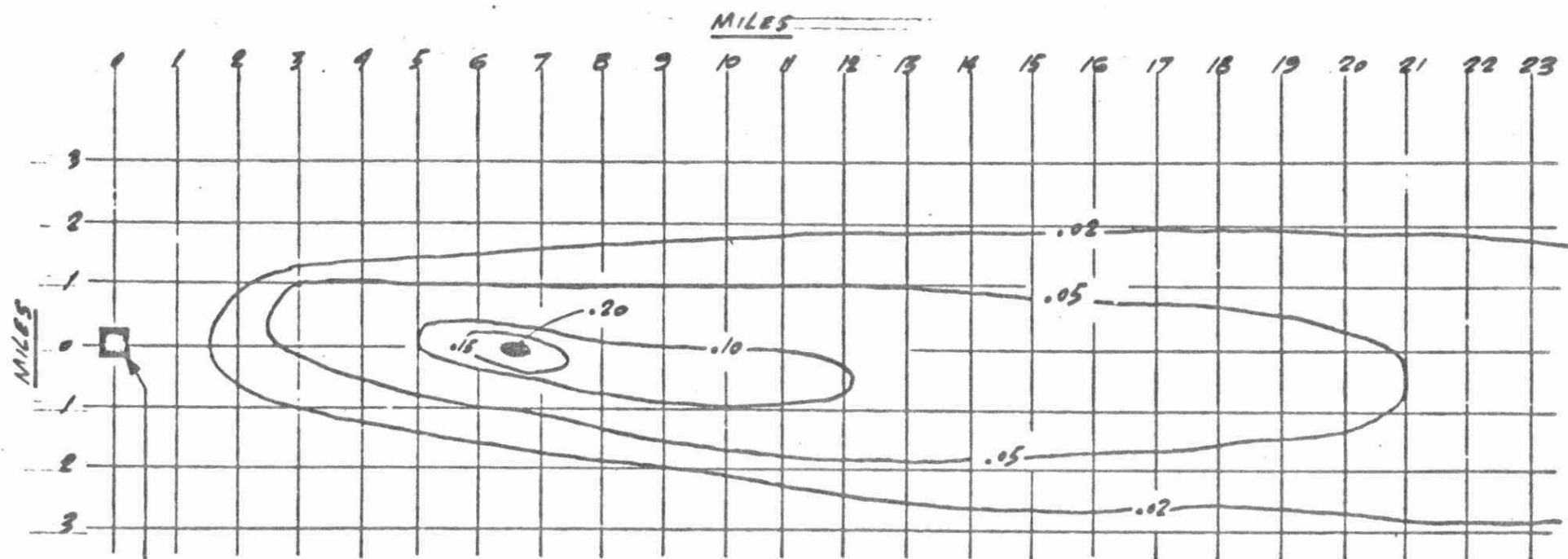
LOCATION  
OF PLANT

PREDICTED DOWNWIND CONCENTRATIONS PARTICULATES

HOURLY AVERAGE  $\mu\text{g}$  PER CU. METER

6,000 MEGAWATT PINEA STATION  
2 - 1000 FT. CHIMNEYS  
FOSSIL FUEL.

FIGURE 16



LOCATION  
OF PLANT.

PREDICTED DOWNWIND CONCENTRATIONS  $SO_2$   
HOURLY AVERAGE P.P.M.

6,000 MEGAWATT POWER STATION  
2 - 1000 FT. CHIMNEYS.  
FOSSIL FUEL  
WITH 75%  $SO_2$  REMOVAL.

FIGURE 17

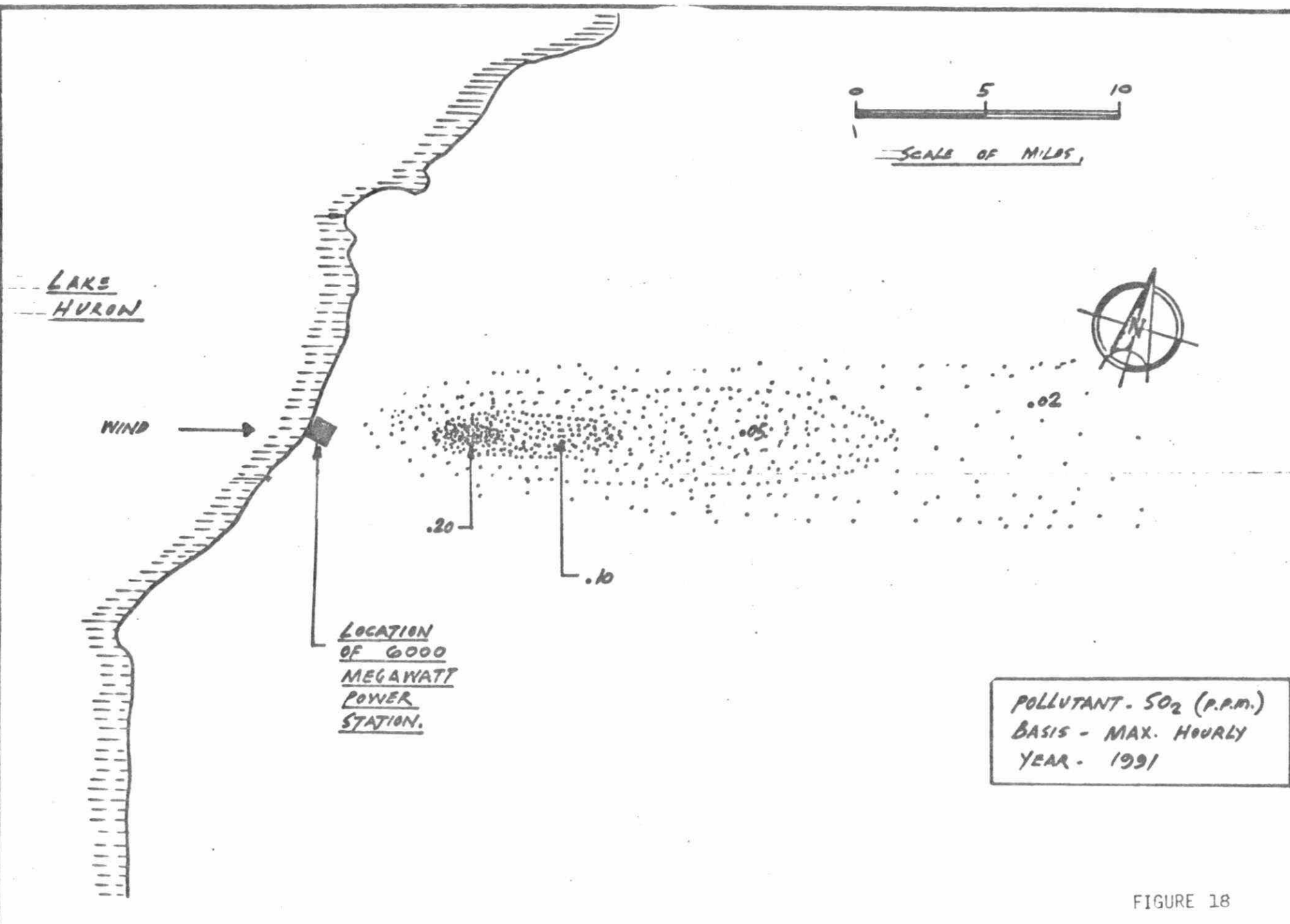


FIGURE 18

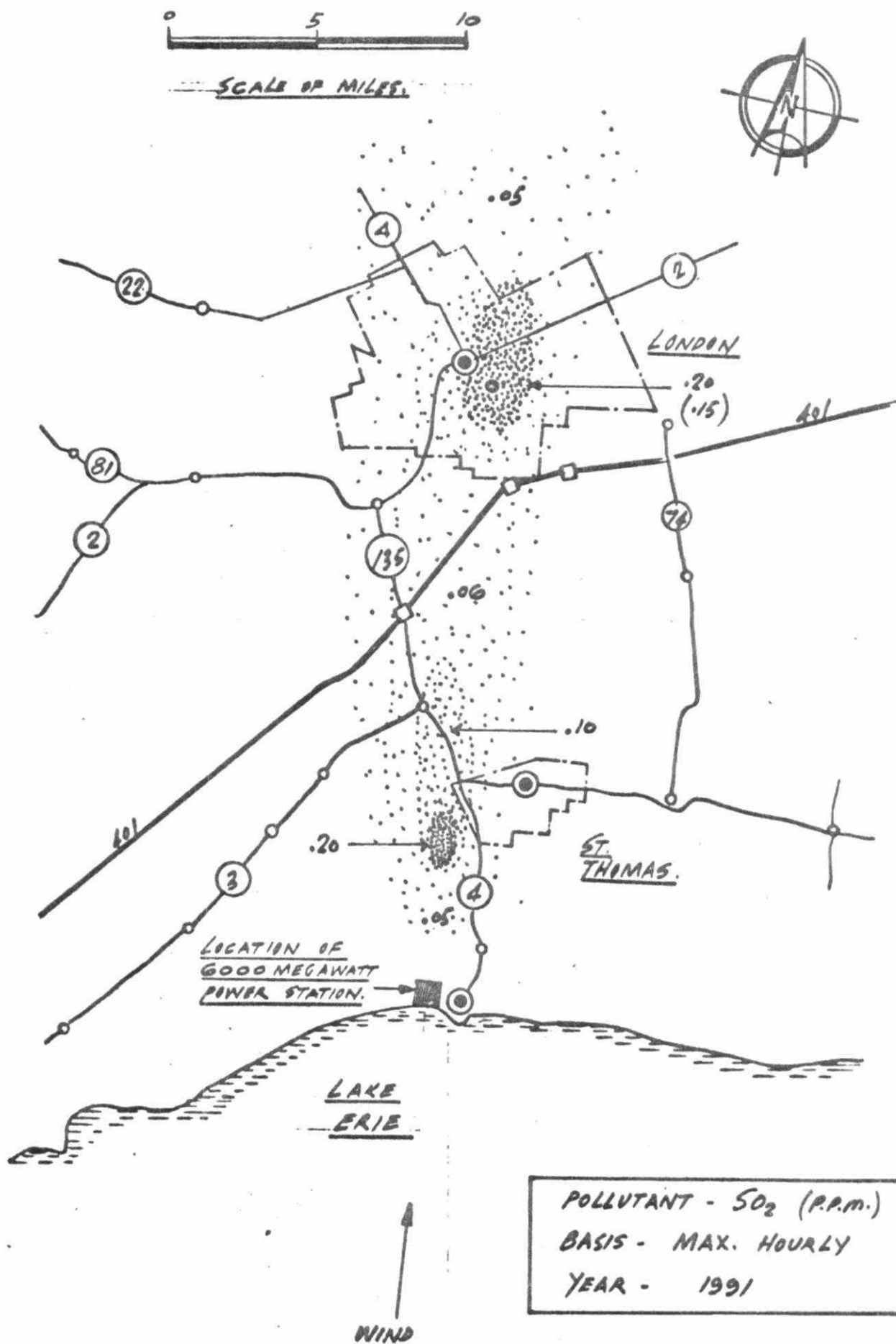
front plant with 75%  $\text{SO}_2$  removal. The concentrations shown also include those of small farming or rural communities and indicate that even large plants can operate within the present Regulations in isolated areas if  $\text{SO}_2$  emissions are reduced, by some means, by 75%.

(ii) Locations Near Moderate-size Cities

Figure 19 depicts the  $\text{SO}_2$  ground-level concentrations for a large hypothetical plant on Lake Erie somewhere south of London, Ontario. London is a sizeable center of population with little industry and the air quality in 1970 was quite good. Should a 6000 MW fossil-fuel generation station be constructed south of London on Lake Erie, then hourly concentrations of  $\text{SO}_2$  may exceed the criteria. The same would be true of St. Thomas or other similar small cities. Therefore large future coal-fired station sites should be at least 30 miles from moderate-size cities, if the Regulations are not to be exceeded. It is particularly important to provide a large enough buffer zone in areas with existing air quality problems.

(iii) Locations Near Very Large Urban Centers

The only area in Ontario by 1991 which is included in this category is the "Golden Horseshoe"



region, Oshawa to Hamilton and including Toronto. The major impact upon the air quality in Toronto is made by the Hearn and the Lakeview generating stations. The present contribution of pollutants from various major sources are shown in Table 11. The resulting air quality in Toronto due to  $\text{SO}_2$  and particulates emission is marginal with respect to the ambient air criteria.<sup>(80)</sup> It is therefore believed that the ambient air criteria will not be met in 1991 with respect to  $\text{SO}_2$  due to the overriding effect of the Lakeview generating station, unless a more extensive  $\text{SO}_2$  abatement program is introduced for the Toronto area.

It is quite evident that this area cannot take the stress of additional emission imposed by expanded fossil-fuel generation capacity.

Ontario Hydro recognizes this and plans no expansion in Toronto. Also, additional fossil-fuel plants in the southern part of the Toronto Centered Region<sup>(81)</sup> should be avoided until  $\text{SO}_2$  and  $\text{NO}_x$  emission control is available.

#### 5.1.4.2 Water Quality

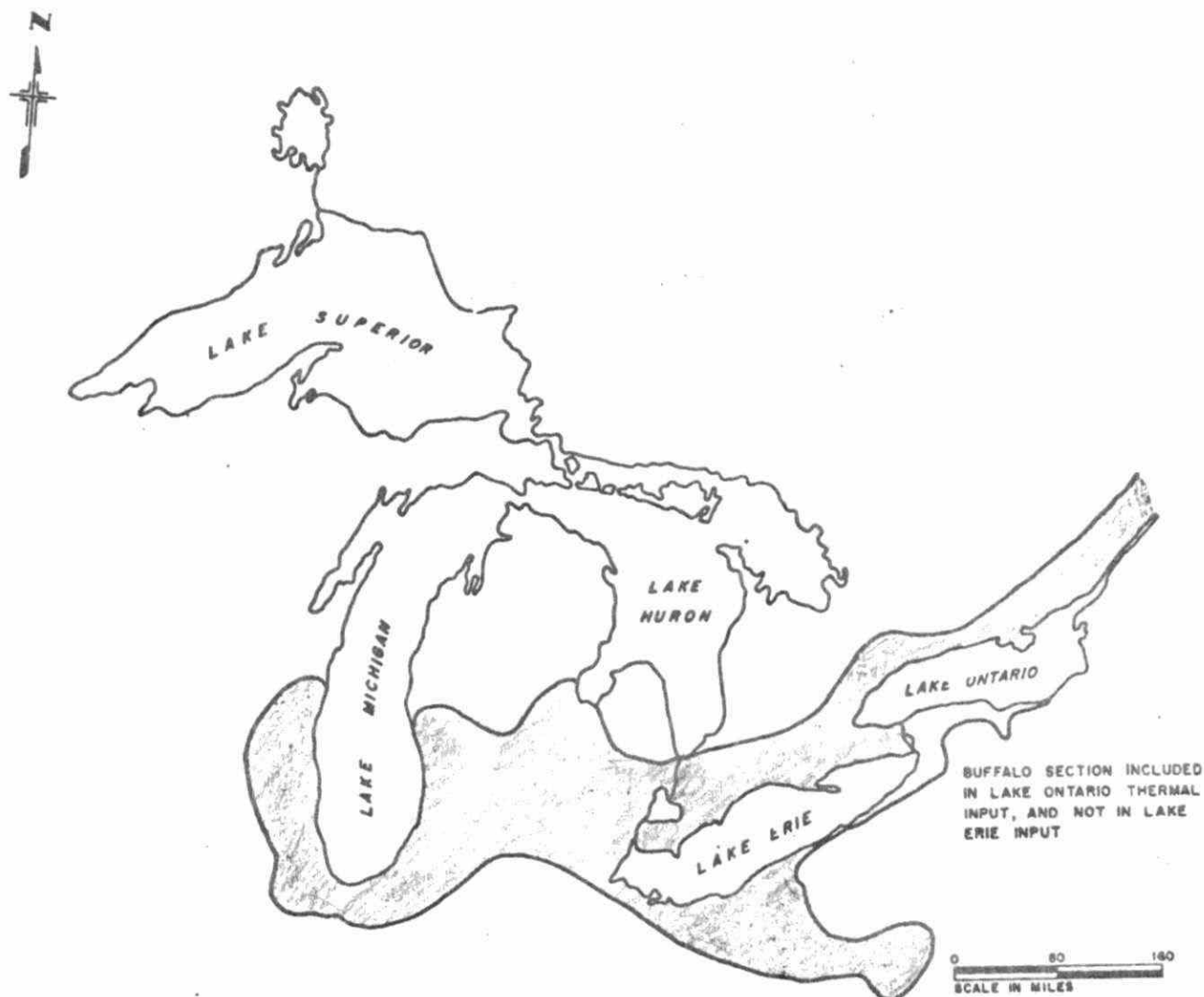
Because of the complexity of defining the overall quality of the aquatic environment, particularly the

long-term effects and the interactions of many different uses, each future power plant should be considered on its own merits.

Some estimates of the heat inputs to the Great Lakes to the year 2000 have been made by H.G. Acres Limited.<sup>(66)</sup> There are also some future water-quality projections in reports by the International Joint Commission.<sup>(27)</sup> While the long-term effects on a given lake have yet to be adequately predicted, it is instructive to see the relative amounts of waste heat being added to the lakes up to the year 2000. These figures are shown on Figure 20 together with the projected boundary of the Great Lakes "urban" megalopolis area. The man-made heat inputs to Lake Ontario and Lake Erie in 2000 is estimated to amount to about 6 percent of the natural input. These estimates also indicate that Canada and the U.S. are presently putting about 50 times the amount of waste heat in these lakes as is being put in Lake Superior and by the year 2000 this ratio will increase to 600 times.

Acres<sup>(82)</sup> and others<sup>(27)</sup> have calculated the temperature rise on the lakes by using an overly simplistic model which considers the lake a completely mixed body of water into which the heat will be homogenously

FIGURE 20



LEGEND



EXTENT OF GREAT LAKES MEGALOPOLIS

Average Man-made Thermal Input in Btu/hour ft<sup>2</sup>

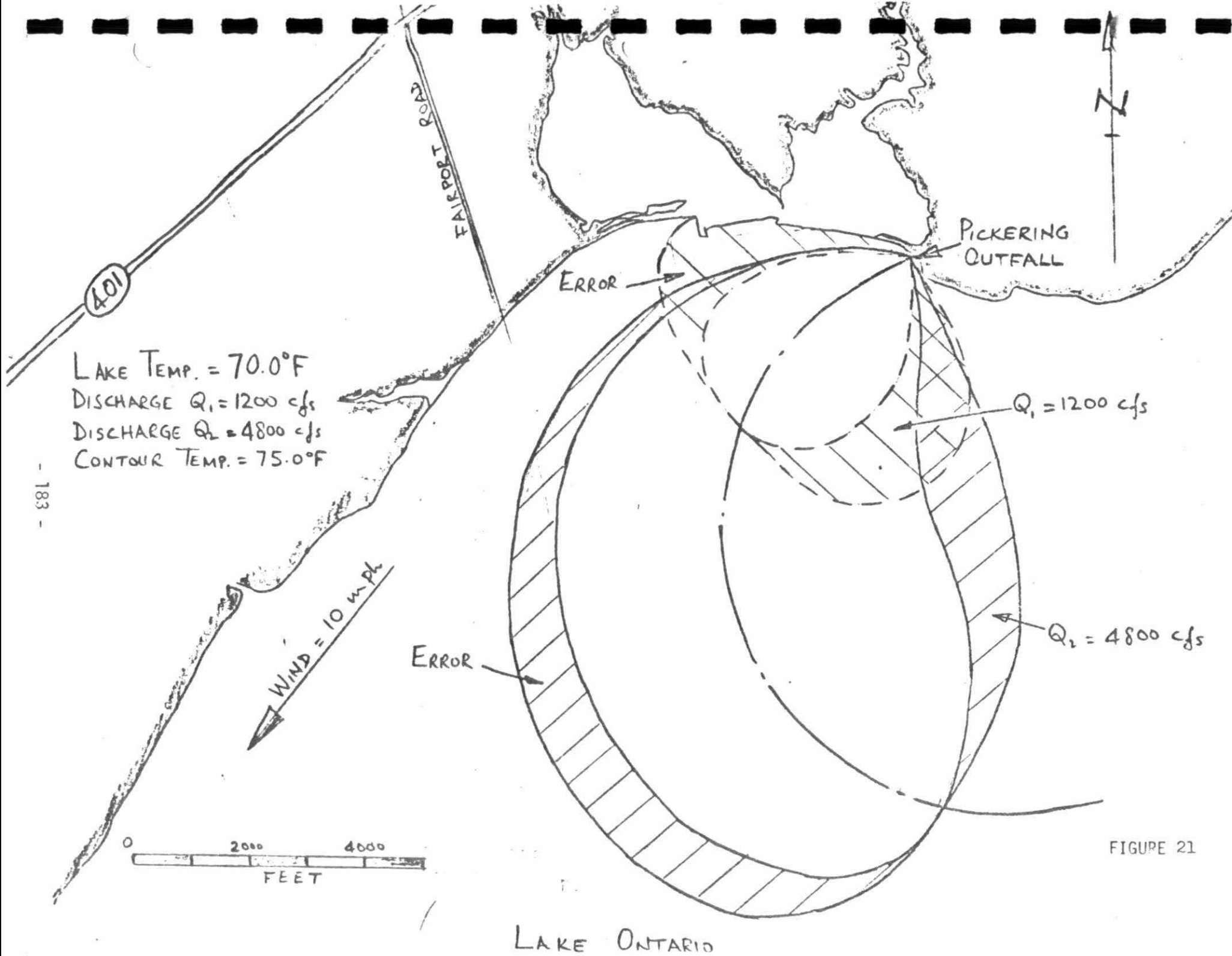
Year	Lake Ontario	Lake Erie	Lake Huron	Lake Michigan	Lake Superior
1968	0.093	.126	0.0077	0.046	0.0021
1980	0.274				
2000	1.26	1.20	0.289	0.52	0.022

EXTENT OF GREAT LAKES MEGALOPOLIS AND  
AVERAGE THERMAL INPUTS TO LAKES

distributed. This could never realistically be expected to occur. Instead one can expect the heated effluents to more or less maintain their integrity for a period of time and move with the wind-drifted currents. These currents are primarily along the shorelines. It is in the shallow waters that the principal spawning, nursery and foraging grounds occur for most fishes and many aquatic invertebrates. Thus, the near-shore water temperatures determine the fate of most of the ecosystems in the lake. Further, these are the areas most affected by thermal discharges.

Local shore-heating effects as shown by the thermal plume of the Pickering Station, Figure 21 (also see Figures 11 and 12) are of the main concern, not only with respect to temperature changes by the near-shore currents, but also with respect to circulation which, can be directly related to the temperature changes. Each plume could travel along the shore, and ultimately, with stations averaging 10 to 20 mile spacing on Lake Erie or Ontario, may result in an almost continuous band of warmed water. Possible effects of thermal discharges on ecosystems of the shoreline were discussed in Chapter 5.1.2.

OWRC has recommended that no further heat be added to



the Western Basin of Lake Erie. This recognizes that this basin is in ecological difficulty and that further stress is undesirable. Any of the Great Lakes could eventually approach the state of the Western Basin of Lake Erie. It is not possible to estimate the time at which this will occur for any given lake because it depends on all aspects of man's activity around the lake.

Water should be recognized as a renewable resource and as with any other renewable resource, be managed so that the use of it does not effect a significant change. The stress placed on the resource should not exceed its ability to make up the loss. If the heat is to be thrown away and it is not put into the water, then it must go into the air or into some other large heat sink. Thus, water quality in the future depends not on extrapolation of present trends, but (1) on the ability of regulatory agencies to formulate suitable guidelines for water-quality preservation and conservation, (2) on the ability of engineers to arrive at innovative solutions to well-known problems, and finally (3) on the willingness of water users of all types to incorporate these solutions.

#### 5.1.4.3 Aesthetic Values

Our knowledge and sense of values have changed significantly and are continuing to change. We are beginning to realize our dependence upon the intricate web of nature, of which we are part. If we are to be concerned about the quality of life, we must give attention to the quality of our man-made environment.

In the planning and construction of a power system, environmental protection and maximum economy are not entirely compatible. While environmental effects cannot be wholly eliminated, they can be minimized by care in design, construction and operation. Aesthetic values should be taken into account by careful siting and design.

With the continuing trend towards very large steam-electric generating stations combined with the public demand that power stations be located outside urban areas, then the increased use of transmission lines is a foregone conclusion. On the other hand, a public outcry is beginning about the aesthetic depreciation of the environment caused by large unsightly transmission towers. Lesser effects include interference with the reception of radio and television signals.

In addition to the transmission lines associated

with power generation facilities, the erection of cooling towers 500 ft. high and stacks 1000 ft. high will also tend to destroy the aesthetic value of the landscape.

Loss of enjoyment of recreational facilities due to pollution-caused problems cannot be measured in pure financial terms, yet, somehow it must be considered in the value of life.

Summarizing, in past energy developments, too little attention has been paid to their effects upon aesthetics, to the detriment of the quality of life. In future, some consideration should be given to these values when planning future energy developments, but it may be necessary to trade one environmental condition against another. Education of the public in these matters and in the consequences of all the alternatives will aid in arriving at the right solutions.

#### 5.1.5 Future Technical Developments

Other energy sources may come into existence over the next twenty years and certainly beyond. The purpose here is to indicate briefly the environmental impact of these developments rather than their technical or economic feasibility. Additional details of these methods may be obtained from a

series of papers in reference 83. All of the proposed methods require extensive research and development before their relative usefulness can be determined. The relative expenditure of money on research and development in the U.S. is of some interest and is listed below:

\$30 million per year on nuclear fusion,  
\$420 million per year on nuclear fission,  
less than \$1 million per year on solar energy,  
\$20 million per year on fuel cells,  
\$2 million per year on magnetohydrodynamics,  
and more than \$30 million per year on coal  
gasification.

(i) Magnetohydrodynamics (MHD)

MHD power generation relies upon the high-velocity flow of a conducting fluid through a transverse magnetic field. Either, hot ionized-gases or a liquid metal, can be used with generators operating at temperatures of 3500 - 5000<sup>0</sup>F and they would produce electrical power from fossil fuels at efficiencies of up to 60%. It is being considered as a topping unit on a conventional steam plant.

Easily ionized substances are added as seeding material to the combustion gases to increase their electrical conductivity.

With the use of a non-sulfur potassium seed, complete elimination of  $\text{SO}_2$  emissions is possible. Thermal pollution is less in the MHD plant compared with the nuclear plant.

A number of difficult equipment problems have to be solved before MHD systems could be escalated to full commercial size.

- (a) The extremely high reactor temperatures require special heat-resistant materials and special heat-exchanger design.
- (b) Corrosion problems caused by the seeding material will be severe.
- (c) The high operating temperatures of the MHD system may create large quantities of  $\text{NO}_x$  in the the exhaust gases.

Development of MHD units up to 40 MW (in Russia) has been pursued in several countries. The effort in North America is at a low ebb at the present.

(ii) Fuel Cells

Fuel cells, in which chemical energy is converted directly into electricity, are virtually

non-polluting systems for the generation of electricity, at efficiencies of 50 - 60% compared to the normal thermal generating station efficiencies of 30 - 40%.

However, before fuel cells can become a major electrical power source, a number of critical problems would have to be overcome.

- (1) Because of their small size, their sensitivity, and the large maintenance requirements, they do not, at present, lend themselves to the construction of large-size electrical generating units.
- (2) Since the best fuel is hydrogen, the large scale fuel cell must be located with pipeline connections to commercial hydrogen manufacturing facilities.
- (3) To date, fuel cells have not been able to operate trouble-free for long periods of time, and their cost is high.

It is believed that they offer a good future potential for Northern Ontario, because they will provide a small impact on the fragile ecology of that region and power will be required in widely separate regions.

(iii) Breeder Reactors

The breeder reactor is based on the principle that certain atoms become fissionable after they have reacted with neutrons. There are atoms of this type; uranium-238, which on reacting with a neutron becomes fissionable plutonium-239 and thorium-232, which becomes fissionable uranium-233. The breeder reaction will make available for use the entire world supply of uranium-238 and thorium-232, with an energy equivalent of several thousand times that of the initial world supply of fossil fuels.

Several types of breeders are being developed: (1) using liquid sodium as coolant, (2) using helium gas at high pressure as coolant, and (3) using molten salt as coolant. In the first two types the reactor chamber will be hermetically sealed (water and air must be excluded from the chamber containing sodium). Experimental breeders have been in operation since 1963 and the first commercial breeder power plant (1000 megawatt capacity) is planned to be in

operation in 1984.

Current fission reactors and future breeder reactors will produce approximately the same types of fission products which will have to be dealt with, however the breeders will contain much greater quantities of radioactive materials at one time. As a result their development is being opposed by some groups particularly in the United States. Some of the hazards of breeder reactors are listed below:

- (1) Higher core temperatures result in higher probability of melt-down of fuel rods with resulting criticality.
- (2) Liquid sodium becomes highly radioactive due to neutron bombardment. When replacement of sodium is necessary, this represents a special disposal problem because of the large volume of contaminated material with hazardous chemical properties.
- (3) In the event of rupture of the heat transfer systems, the liquid sodium

would react explosively in the water.

- (4) Fast breeders will contain large quantities of plutonium which has a lower critical mass (13 lbs.) than uranium-235 (20 lbs.) and accidental failure could result in nuclear explosion, although the chance is remote.

(iv) Fusion Reactors

Fusion reactions based on the use of Deuterium ( $D_2$ ) may eventually become a major source of electrical power on a long-term basis because there is an almost inexhaustible source of deuterium in sea water. In addition, this type of reaction produces only non-polluting and non-radioactive gases, with a very small amount of disposable wastes along with electrical energy conversion efficiencies of 90%. From an environmental standpoint, this method of generating power is highly desirable because:

- (1) There are no radioactive waste products to process or store.
- (2) There is no danger of nuclear explosion. Any failure in the system containing the plasma will

result in immediate quenching of the reaction since it cannot occur under ordinary conditions.

- (3) In the event of failure, the total release of radioactive materials would be very small. The only radio-nuclide released would be tritium of which there would be only 10 kam in the reactor at one time.
- (4) There is the possibility of converting plasma energy directly into electrical energy, thereby eliminating the problem of waste heat.

The chief environmental problem expected to arise from fusion reactors is the escape of tritium during operation. The possible extent of this release is not known at present. However, the reactions occur only at temperatures of 100 million to 500 million degrees K, temperatures at which any mechanical container would be vaporized. The difficult task presently under development is to devise magnetic bottles in which to contain these reactions. Estimates vary greatly as to the time when controlled fusion

may be achieved.

(v) Solar Power

Direct conversion of sunlight is an environmentally ideal power source. The possible use of solar energy for the generation of electrical power has three alternative methods which could be considered.<sup>(84)</sup>

- (1) Transmission of power, collected in space by means of a satellite system via microwave to a receiving system located on earth.
- (2) The collection of energy on the surface of the land by solar cells or storage media with its conversion to electrical power.
- (3) The location of a floating power station in warm ocean waters, which would be used for power generation.

It would appear that none of the above methods could be developed commercially on a large-scale before the next century.

## 5.2. Impact of Energy Use By Transportation

### 5.2.1 Air Pollution

In 1970 the transportation sector accounted for 22% of the total energy consumed in Ontario (Table XVIII). Although its relative energy consumption is expected to decrease by 1990, the total energy consumption will more than double during this period. Oil or fuels derived from oil provide the largest energy source of the transportation sector now and in the foreseeable future (Table XIX). As a result almost all of the pollution caused by the transportation sector is related to the consumption of liquid fuels.

Ideally, the only products of combustion of liquid fuels would be water vapour and carbon dioxide. However, emissions by some transportation sources are far from ideal, resulting in varying degrees of air pollution.

The emissions that fall into the category of air pollutants include: lead compounds, particulate matter, carbon monoxide (CO), oxides of nitrogen ( $\text{NO}_x$ ), unburned and partially oxidized hydrocarbons (HC), and sulfur oxides ( $\text{SO}_x$ ). The formation of these products is a direct result of the combustion of hydrocarbon fuels in air. The extent of the emissions depends on many factors, some of which are inherent in the design of the engine.

TABLE XVIII  
ONTARIO'S ENERGY DEMAND BY CONSUMERS

Consumer	10 <sup>12</sup> BTU					
	(in brackets: percentages of total)					
	1970		1980		1990	
Transportation*	394	(22)	625	(19)	923	(18)
Residential and Commercial *	537	(30)	743	(23)	984	(19)
Industrial *	616	(35)	1013	(32)	1545	(29)
Electric Utilities	229	(13)	830	(26)	1785	(34)
TOTAL DEMAND	1776	(100)	3211	(100)	5237	(100)

\* Excluding Electrical Energy

TABLE XIX  
ENERGY DEMAND OF TRANSPORTATION BY SOURCE

	10 <sup>12</sup> BTU					
	(in brackets: percentages of total)					
	1970		1980		1990	
Oil	393	(99.8)	608	(97.3)	873	(93.2)
Natural gas and Propane	negligible		15	( 2.4)	50	( 5.3)
Electricity	1	( 0.2)	2	( 0.3)	14	( 1.5)
TOTAL	394	(100)	625	(100)	937	(100)

In Toronto transportation accounted for over 97% of the CO, about 68% of the HC and 22% of the NO<sub>x</sub> emission of all power consuming sources (Table II). Pollutant emission by transportation therefore affects the environment at the present time, particularly since the pollutants are emitted at ground level.

#### 5.2.1.1 Emissions by Automotive Sources

Automobiles are the largest single emission source of carbon monoxide and lead in the air. Figure 22 summarizes the expected automotive emission for the next twenty years with and without abatement controls. Without controls the total emission will more than double during this period as a result of an ever-increasing vehicle population (Table XX).

Proposed legislation calls for a 90% reduction of pollutant emission by 1976 (Table XXI). As a result, emission of the post-1976 model vehicle population will be reduced effectively but pre-1969 model cars will continue to be the major contributor to overall automotive emission until replaced by more recent models. At about 1978 pre-1969 models are expected to constitute 10% of the total vehicle population, their emission, however, will be about the same as the emission of the remaining 90% of vehicles.

- (i) Carbon Monoxide (CO) emission results from incomplete combustion of fuel in the internal combustion (IC) engine. Exhaust gases of uncontrolled vehicles contain

TABLE XX  
ESTIMATED AUTOMOTIVE EMISSIONS  
IN ONTARIO

Year	Total Emission									Vehicle <sup>1</sup> Population
	Carbon Monoxide <sup>1</sup> (1000 tons/yr.)		Hydrocarbons <sup>1</sup> (1000 tons/yr.)		Nitrogen Oxides <sup>1</sup> (1000 tons/yr.)		Lead <sup>2</sup> (1000 tons/yr.)		Sulphur Dioxide <sup>3</sup> (1000 tons/yr.)	
	No Controls	Controlled	No Controls	Controlled	No Controls	Controlled	No Controls	Controlled	No Controls	
1970	2,487	2,241	364	339	127	142	7.2	7.2	7.84	2,625,000
1974	2,968	2,185	434	312	152	167	8.8	8.8	9.60	3,133,000
1975	3,000	1,402	439	226	192	167	9.2	3.8	10.00	3,200,000
1980	3,700	874	541	125	237	89	11.4	0.9	12.40	3,900,000
1985	4,450	675	666	106	291	37	13.2	-	14.40	4,800,000
1990	5,600	717	819	122	358	29	17.2	-	18.70	5,900,000

(1) Estimated by J.G. Jefferies, Chief, Automotive Emissions Control Section, Air Management Branch, Ministry of the Environment

(2) Based on estimated average lead content of gasoline sold in Ontario (2.6 g. lead/US gal.)

(3) Based on estimated average sulphur content of 0.04% of Ontario gasoline.

TABLE XXI  
AUTOMOTIVE EMISSION CONTROL REQUIREMENTS DUE TO FEDERAL LEGISLATION OR  
PROPOSED FEDERAL LEGISLATION

Model Year	Emissions in g/vehicle mile						Possible Control Methods	
	Hydrocarbons			Carbon Monoxide		Nitrogen Oxides		
	Emission	%	Control	Emission	%	Emission		%
Pre-1969	17.0	(+13.8)*	0	125	0	5	0	None
1969	5.8	(+6.2)**	61	60	52	6	-20* <del>‡</del>	Thermal exhaust gas reactors, air pumps crankcase blowby recircu- lation.
1970	3.8	(+6.2)**	68	39	69	6	-20* <del>‡</del>	Engine modifications.
1971	3.4	(+1.0)**	82	39	69	6	-20* <del>‡</del>	Evaporative controls.
1973	3.4	(+0.3)**	88	39	69	3	40	Exhaust gas recirculation.
1976	0.4	(+0.3)**	98	3.4	97	0.4	92	Catalytic devices.

\* Hydrocarbon emissions from crankcase blowby and evaporative losses.

\*\* Hydrocarbon emissions from evaporative losses.

\*\*

\* Higher engine temperatures occur as a result of the control systems. These higher temperatures cause an increase in the emission of nitrogen oxides. No control required until 1973.

3 - 4% CO. Figure 22 projects CO emissions assuming enforcement of present control measures. By about 1990 the total CO emission will be reduced by 85%. Presently CO air quality criteria are only occasionally exceeded in areas of high traffic density, although the arithmetic mean concentration approaches the 24 hour standard. It appears that 1972 CO emission standards (69% CO reduction) will suffice to control CO emission for the foreseeable future. As a result, CO emissions are not believed to represent a serious problem.

- (ii) Hydrocarbon (HC) emissions result from three sources in automobiles (Figure 23). Increasingly stricter controls will effectively reduce HC emission until 1985 and result in a reduction of total HC emission until about 1982 (Figure 5). After 1985 HC emission from automotive sources may be expected to increase again as a result of a growing vehicle population. Some hydrocarbon species take part in the formation of photochemical smog, which will be discussed later.
- (iii) Nitrogen Oxide ( $\text{NO}_x$ ) emission is expected to increase up to 1975 as a result of both increasing vehicle population and increased  $\text{NO}_x$  emission of 1969 to 1972 models. A 40% reduction of  $\text{NO}_x$  emission is expected from 1973 vehicles as a result of  $\text{NO}_x$  standards that are coming into

FIG. 22 - PROJECTED AUTOMOTIVE EMISSIONS FOR ONTARIO

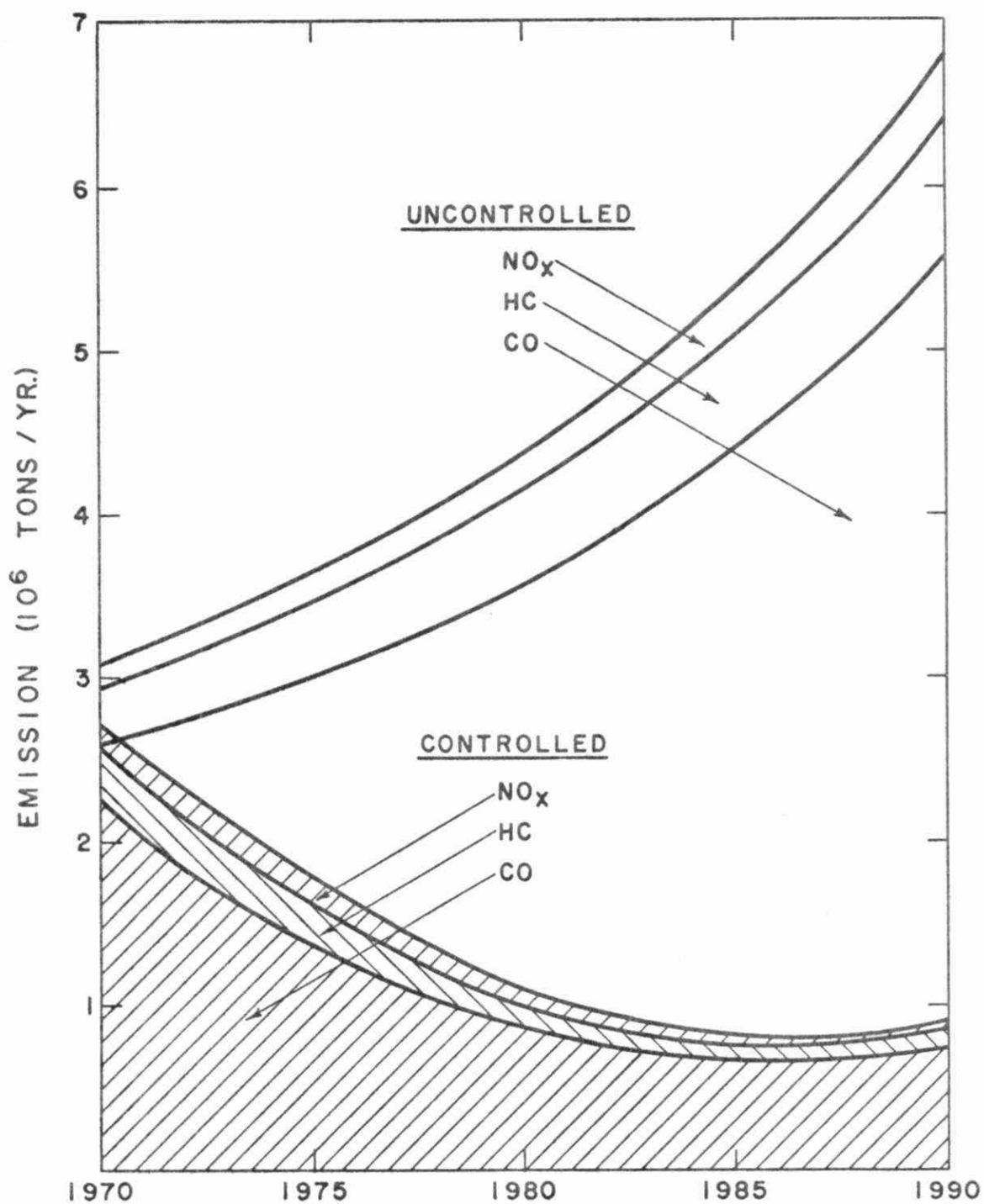
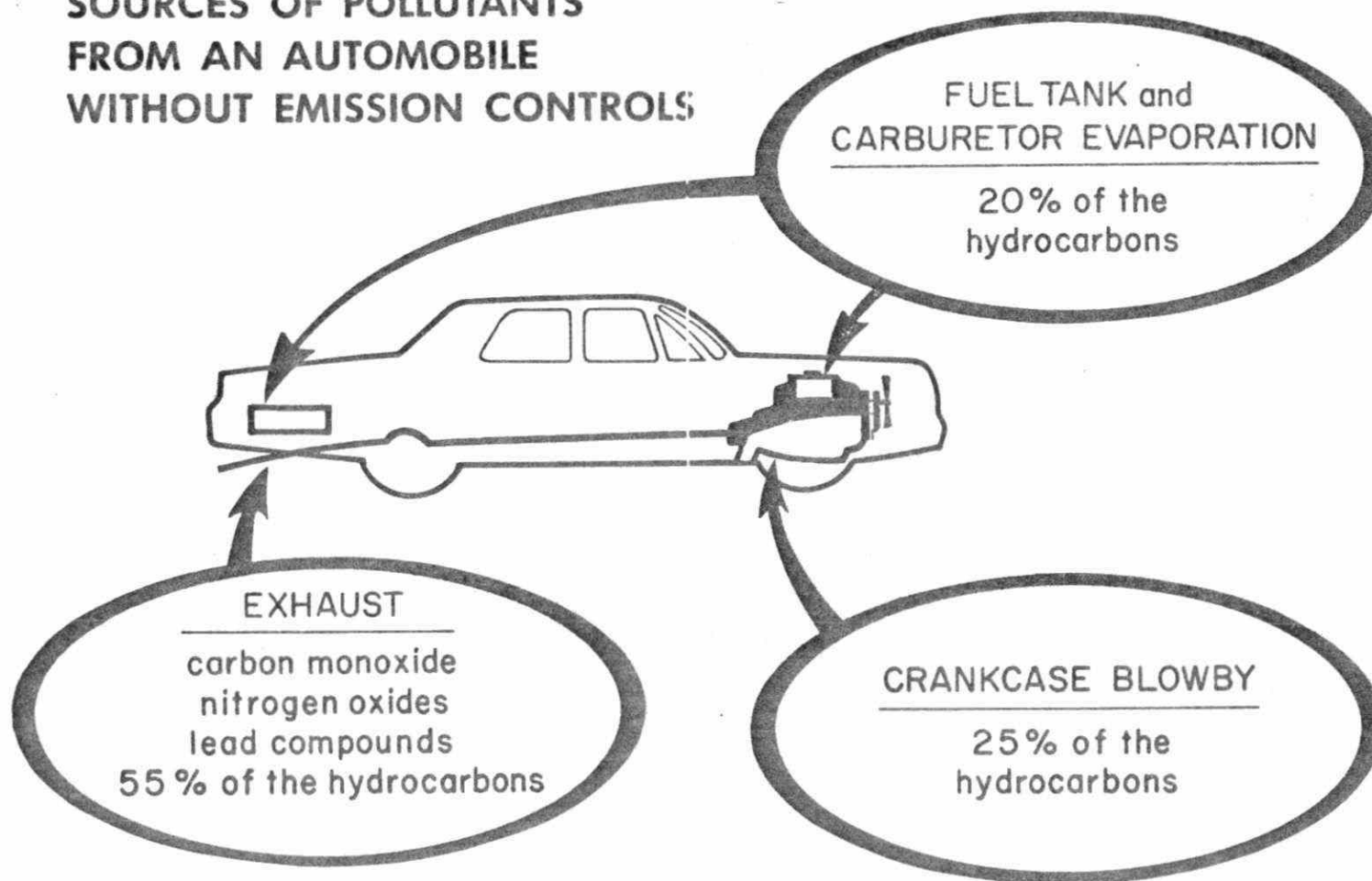


FIGURE 23.

**SOURCES OF POLLUTANTS  
FROM AN AUTOMOBILE  
WITHOUT EMISSION CONTROLS**



force for the 1973 model year. However, the increase of  $\text{NO}_x$  emission by the total vehicle population will not come to a halt until after 1976 when Federal emission standards for 1976 models are scheduled to come into effect (Table XXI), which call for a 92% reduction of  $\text{NO}_x$  relative to pre-1969 models. From 1975 to 1990  $\text{NO}_x$  emissions will decrease as a result of the 1976 emission control standards. Catalytic mufflers are presently being developed to achieve the 1976 standards.  $\text{NO}_x$  is also a smog ingredient.

- (iv) Lead Particulate emission from cars originates from the presence of tetraethyl lead (TEL) additive in gasolines. Lead from gasoline powered vehicles is by far the largest single source of airborne lead. Lead emissions by motor vehicles is expected to increase until 1975 and to decrease after that as a result of usage of unleaded or low-lead gasoline which is required by vehicles equipped with catalytic mufflers. In Ontario urban areas typical average lead values in ambient air are 1 to 5  $\mu\text{g}/\text{m}^3$  air which is well below the present standard for airborne lead of 15  $\mu\text{g}/\text{m}^3$ . However, in the event of unrestricted and continuing use of lead in gasoline after 1975, a substantial increase in lead in urban air can be expected.
- (v) Particulate Matter Automobiles directly and indirectly responsible for substantial amounts of airborne parti-

culate matter in urban areas. Most recently, traffic generated airborne particulate was estimated at 35 million pounds per year in Metropolitan Toronto (Table XXII). This accounted for about 44% of the total emissions of particulate matter in 1971 in this area.

Heavy-duty diesel emissions of CO, HC and NO<sub>x</sub> by trucks are minor compared with automotive emission (Table XXIII). Particulate emission, however, is substantial. Exhaust odor is one of the more persistent emission problems associated with diesel engines. Chemical characterization studies of the composition of odorants are as yet incomplete.<sup>(85)</sup> Among the identified substances were photochemically reactive compounds of high smog-forming potential. It is for this reason that diesel emission should not be overlooked. Their contribution to smog formation should be carefully studied. The solid particulate matter may also carry malodorous hydrocarbon substances adsorbed on to its surface.

#### 5.2.1.2 Potential Health Effects of Automotive Emissions

##### (i) Formation of Photochemical Smog

It is now well understood that HC's and nitrogen oxides are the main components of photochemical smog formation and that intermediate reaction products such as oxidants and aldehydes are responsible for most of the plant

T A B L E XXII

TRAFFIC GENERATED AIRBORNE PARTICULATE MATTER IN  
METROPOLITAN TORONTO 1971

SOURCE OF EMISSION	MM LBS/YR.
Gasoline powered vehicles	4.65
Diesel       "       "	1.32
Brake shoe lining wear	0.27
Tire wear	6.50
Road wear, sand/salt, other dust on road	21.91
Total	34.65

Data from:

Preliminary assessments of sources, quantities, effects and potential abatement strategies for airborne particulate in Metropolitan Toronto, Ministry of the Environment, Air and Land Pollution Control Division, Air Management Branch, Toronto, Ontario, Canada. 1972.

TABLE XXIII

ONTARIO DIESEL VEHICLES POLLUTANT EMISSIONS

(1000 Tons Per Year)

<u>Pollutant</u>	<u>1970</u>	<u>1975</u>	<u>1980</u>
Carbon Monoxide	62.7	71.9	72.4
Hydrocarbons	7.6	8.7	6.9
Nitrogen Oxides	8.7	10.0	8.3

damage and human discomfort caused by photochemical smog. (86,87) In many U.S. cities automotive emission is the main contributor to photochemical smog formation. For many regions the factors leading to smog formation are now well understood. It should be pointed out that these factors may differ quantitatively from region to region due to different local atmospheric conditions.

Relatively little is known about the origin of photochemical smog formation in Ontario. Studies by the Air Management Branch are underway to determine if and under what conditions it may form. In view of the uncertainty of an acceptable limit of HC in ambient air the present and future impact of automotive HC emission on the environment may not fully be evaluated. If we agree that the present HC concentration in ambient air is acceptable, then there appears to be no need to restrict HC emission to less than the 88% reduction noted in Table XXI as proposed for 1973. Emission control systems which meet 1973 standards are considerably less expensive (Table XXIV) than catalytic devices, which would be required to meet the proposed 1976 federal standards.

Concentrations of  $\text{NO}_x$  in ambient air frequently exceeds the air quality criteria in areas of high traffic density.  $\text{NO}_x$  is catalytically enhancing photochemical

TABLE XXIV

ESTIMATED INVESTMENT AND OPERATING COSTS  
 FOR CONTROL OF AIR POLLUTION BY AUTOMOBILES  
 FOR 1969 - 1976 MODELS\*

Model Year	Investment Per Car \$	Change in Maintenance and Operating Costs per year \$	Rel. Fuel Consumption (%)
Pre-1969	--	--	100
1969	17	-5.10	100
1970	17	-5.10	100
1971	50	-2.70	100
1973	75-130	35-65	107 approx. 110
1976	315-600	65-200	115-125

\* Data from reference 89 and 90.

smog formation. Therefore, the control of  $\text{NO}_x$  emission is an important strategy in reducing or preventing future occurrence of photochemical smog.

(ii) Lead and Its Effect on Human Health

With traces of lead in air, soil and on plants, lead finds its way into the human body by inhalation and ingestion. Probably one-third of the lead in U.S. population is inhaled lead of automotive emissions. (88)

There are controversial reports about the effect of lead on human health in sub-toxic concentrations. As a summary, it may be concluded that -

- (1) Lead has no known beneficial function in human metabolism.
- (2) Lead is a cumulative poison in man.
- (3) It can harm the central nervous system and may interfere adversely with the development of red blood cells and may cause brain damage to children.
- (4) Accumulation of lead in Americans is relatively close to the threshold concentrations of clinical poisoning.

California recently adopted a 30-day standard for airborne lead of  $1.5 \text{ ug/m}^3$  air which is in sharp contrast to Ontario's present standard of  $10 \text{ ug/m}^3$ . However, the Ontario ambient standard for lead will soon be

reduced to 5 ug/m<sup>3</sup>. This will require reduction of the amount of TEL added to gasoline. Reduction or removal of TEL has to be compensated by the addition of gasoline components of higher octane number. Thus, unleaded gasoline will contain a higher fraction of aromatic hydrocarbons and isoparaffins and will be more expensive. Estimates of the increased cost range from \$10 per year per automobile to 5.17 cents per U.S. gallon of gasoline. The incentive for consumers to continue to use leaded gasoline over unleaded gasoline therefore is high.

At present no satisfactory data are available to suggest a significant relationship between increased aromatic content and rises in photochemical reactivity.<sup>(91)</sup> Increasing the aromatic content of fuels could have an effect on the quantity of polynuclear aromatic hydrocarbons (carcinogens) in automotive exhaust. Polynuclear aromatics (PNA) probably rise with the concentration of aromatics in the fuel, but they also appear to fall with the elimination of lead.

Automotive sources currently constitute between 2 and 10% of total PNA emissions in the U.S. depending upon the specific basis used for analysis. It is important

to note, however, that any concern over PNA's emanating from auto exhausts should be shortlived. Incorporation of exhaust gas treatment systems, especially a catalytic system, will result in selective decreases in polynuclear aromatics.

#### 5.2.1.3 Alternatives to the Internal Combustion Engine (ICE)

Atmospheric air pollution from gasoline powered ICE's poses an environmental problem in many urban areas. Substantial improvement in regional air quality is being experienced as a result of automotive engine design changes and incorporation of emission control devices, but growing car populations threaten to negate these advances. Since further reductions in emission controlled gasoline powered ICE's are difficult, other methods of reducing passenger car exhaust emissions have been sought. These methods have ranged from the use of alternative ICE fuels to the replacement of the ICE with a different power plant.

Any alternatives of the gasoline powered ICE must meet three criteria.

- (1) Significant reduction in pollution.
- (2) Comparable cost.
- (3) Comparable performance.

Table XXV shows comparative emissions of the gasoline powered ICE and its most potential competitors.

TABLE XXV  
EMISSION DATA FOR VARIOUS ENGINES  
AND THE 1976 EMISSION STANDARD

	HC	Exhaust Emission CO	(g/mile) NO <sub>x</sub>
Gasoline IC Engine (1970)	3.8	39	6.0
Natural Gas IC Engine	1.5	6	1.5
Wankel Engine	1.8	23	2.2
Steam Car (Rankine)	0.2 - 0.7	1 - 4	0.15-0.4
Gas Turbine	0.5 - 1.2	3 - 7	1.3 -5.2
Stirling Engine	0.006	0.3	2.2
1976 Emission Standards	0.41	3.4	0.4

Data from reference 92.

Natural gas, (methane) and liquefied natural gas (propane) have had wide publicity as substitutes for gasoline. Although these fuels have chemical characteristics that permit cleaner exhaust emissions, the crisis over natural gas supplies, problems of distribution, and the added complexities of the fuel system probably preclude general use by the motoring public. Use of these fuels in urban-operated fleets, however, is economically feasible and will probably increase in the future. Of particular interest is the dual-fuel system which allows the operators of such vehicles to use alternatively either liquefied natural gas or gasoline. This system is presently undergoing an extensive test program in the U.S. Preliminary results indicate that considerable cost savings in fuel and maintenance can be achieved. (93)

The Wankel engine is an ICE which employs a rotor rather than conventional piston for propulsion. Cars powered with Wankel engines are presently produced by German and Japanese manufacturers. The Wankel engine's superior performance and lower pollutant emission provide also a great incentive for domestic car producers to consider it as a potential substitute for

the conventional ICE, although additional emission reduction is required to meet 1976 emission standards.

The steam engine, gas turbine and Stirling engine are external combustion engines (ECE), i.e. the engine is heated externally. Gas turbines are powered by the hot expanding gases of fuel combustion. Both the steam engine and the Stirling engine use external combustion of fuel to produce high temperatures and pressure in a closed system containing a working medium such as water, ammonia or an inert gas which provides the power for a piston engine. From a standpoint of pollutant emission ECE's are attractive alternatives to the ICE although some additional emission control is required to meet 1976 standards.

Alternatives to heat engines are electric motors powered by fuel cells or rechargeable batteries. Battery-powered vehicles themselves produce no exhaust or unburned fuel emissions and are therefore particularly attractive for urban use. The main difficulty that must be overcome in developing practical electric automobiles for general use is the present lack of low-cost batteries having sufficient energy storage capability per unit weight. A major improvement in specific energy without sacrificing specific power is required before practical electric passenger vehicles for general use will become a reality.

Present analyses of all competing systems indicate, that into the 1980's, the best combination of costs, utility, and potential for reduced pollution output is the current gasoline-powered automobile.

#### 5.2.1.4 Complementary Strategies for Reducing Air Pollution

Increasing public opinion and legislation indicate that serious efforts to reduce the amount of air pollution caused by transportation are necessary. Although such reduction will be highly dependent on controlling emissions at their source, urban planning, transportation planning, and traffic engineering can significantly improve air quality. Such measures should complement a source control strategy for most effective emission reduction.

Measures that can be used include the improvement of traffic flow, the dispersal of motor vehicle traffic in time and space, the reduction of the overall amount of vehicular travel, and greater use of vehicles with low emission characteristics. The implementation of these measures requires coordination at all levels of government.

These measures, which supplement the efforts of government and industry to reduce automotive emissions at the source, encompass the following means of reducing harmful exposure to air pollutants:

- (1) Smoothing the flow of traffic.
- (2) Reducing concentrations of traffic, both

geographically and by time of day.

(3) Reducing the total amount of travel.

Table XXVI lists a number of techniques previously used, or at least proposed in the context of improving the capacity and quality of urban transportation systems in the U.S. Not all the techniques will apply to every city, but some should. Their aggregate impact will increase the likelihood of improving air quality standards.

While it is impossible to place a precise measure of effectiveness on each technique, there is sufficient knowledge to assign an approximate value. This, shown on the table as "Probable Effectiveness," uses a scale of 1 (least effective) through 5 (most effective). The effectiveness of most techniques in reducing air pollution varies from one city to another for such reasons as the extent to which the technique is already in use, the adequacy of the area's transportation system, or the climate of the area. Some techniques may be most appropriately applied during severe pollution episodes.

In Toronto with an automobile population of 800,000 the air quality is affected by the exhaust emissions of automobiles. An implementation of a program involving several techniques of Table XXVI to reduce downtown traffic congestion may also potentially reduce air pollution from automobile sources. Up to the present time automotive emission controls have been

TABLE XXVI

TECHNIQUES FOR IMPROVING TRAFFIC FLOW, FOR REDUCING  
POLLUTION CONCENTRATION, AND FOR REDUCING AUTO TRAFFIC

Techniques for Improving Traffic Flow	Probable Effectiveness
A. Freeways	
1. Reverse-lane operations	3
2. Driver advisory displays	1
3. Ramp control	2
4. Interchange design	2
B. Arterials	
1. Alinement	1
2. Widening intersections	3
3. Parking restrictions	2
4. Signal progression	2
5. Reversible lanes	3
6. Reversible one-way streets	3
7. Helicopter reports	2
C. Downtown Distribution	
1. Traffic responsive control	5
2. One-way street operations	3
3. Loading regulations	3
4. Pedestrian control	1
5. Traffic Operations Program to Increase Capacity and Safety (TOPICS)	5
<u>Techniques for Reducing Pollution Concentration</u>	
A. Staggered Work Hours	3
B. Roadway Concentrations	2
C. Cross-sections	2
D. Elevated, At-grade, Depressed Roadways	2
<u>Techniques for Reducing Auto Traffic</u>	
A. Transit Operations	
1. Bus lanes on city streets	1
2. Bus lanes on freeways	1
3. One-way streets with two-way buses	1
4. Park-ride, kiss-ride	3
5. Service improvements and cost reductions	2
B. Regulation	
1. Parking bans	4
2. Auto-free zones	4
3. Gasoline rationing	5
4. Idling restrictions	2
5. Four-day, forty-hour week	2
C. Pricing Policy	
1. Parking policy	2
2. Road-user tax	5
3. Gasoline tax	5
4. Car pool incentives	2
D. Planned Unit Development	2

Table reference 94.

employed as the basic abatement strategy. The Canadian Federal government has followed the emission standards established by the EPA in the United States. They are based upon what is needed in cities with serious photochemical smog problems such as Los Angeles. Because such control measures are not required in all areas of North America, a considerable controversy has arisen as to whether these standards should be uniformly applied to all areas. The Ministry of the Environment has questioned the necessity of these measures in Ontario where the prospect of photochemical smog formation has not been established. The less intense sunshine and generally good surface winds in Ontario as compared to Los Angeles greatly reduce the chances of photochemical smog formation here. The cost to Ontario residents for automotive emission devices needed to meet the 1976 standards would be about \$100 million per year. Consequently, the question being asked is; "Is this a good investment?" The total problem should be carefully reviewed and information needed to correctly answer the question should be obtained.

#### 5.2.1.2 Aircraft Sources

The major concern with aircraft exhaust emissions has been with regard to their effect on the environment surrounding individual airports. The identification of the actual levels of exhaust gas pollutants at a particular airport is

complicated by the frequency of operations and the prevailing weather conditions. Thus, the actual levels existing locally may vary over a large range with the time of day, as well as with variations in weather and other emission sources.

Aircrafts emit a variety of pollutants which except for lead, are common to all aircrafts, although the proportion of each emitted pollutant may vary depending on the type of aircraft engine.

Presently aviation uses two inherently different types of engines as power sources:

- (a) the conventional gasoline powered internal combustion engine (ICE) and

- (b) the gas turbine engine

Emissions of airplanes powered by the ICE are similar to those discussed in the section of air pollution by automotive sources.

The gas turbine engine is the most efficient combustion engine in transport use today, from the standpoint of air pollution. The combustion process in gas turbines differs from that in gasoline engines in that it occurs at constant pressure, and with a large excess of combustion air. The exhaust emission of hydrocarbons, carbon monoxide, oxides of nitrogen, aldehydes and particulate matter varies greatly with the operational modes of the aircrafts but invariably emissions are higher

at ground operations, landing approach and climb-out.

Due to different quantities of pollutant emission the composition of various air pollutants at airports and in surrounding areas largely depends on the relative proportion of the class of aircraft frequenting the airport. On the other hand, the quantity of pollutant emission is reflected very closely by the volume of aircraft activity and the size of aircraft and may be expected to increase as operations and size of the aircraft increase.

Table XXVII summarizes total aircraft movements at four major Ontario airports. Although all considered airports are comparable in total aircraft movements, their impact on the environment is greatly different, due to the difference in distribution of class of aircraft.

Toronto International Airport (TIA) may be expected to have by far the largest impact, as a result of the significantly large- activity of air carriers (Table XXVIII) which are the major contributors to total pollutant emission by aircraft. TIA therefore was selected for the following evaluation of the impact of aircraft emission on the environment.

Calculated pollutant emission at TIA is compared with the emission at one U.S. airport of similar aircraft activity (See Tables XXIX and XXX). Estimated emissions of TIA and Washington National Airport (WNA) are comparable in magnitude

TABLE XXVII

## Total Aircraft Movement

	1970	1971
	(thousands)	
Toronto International Airport (TIA)	208	199
Toronto Island Airport (TI)	190	191
Ottawa International Airport (OIA)	190	202
Hamilton City Airport (HCA)	164	194

Data from reference 95.

TABLE XXVIII

Itinerant Movements\* 1971

	Total (thousands)	Air Carrier (thousands)	Commercial (thousands)	Private & Govt. & Military (thousands)
TIA	177	122	17	38
TI	51	0.4	32	19
OIA	91	27	23	41
HCA	47	2.4	27	18

Data from reference 95.

\*Aircraft entering or leaving airport tower control zone.

TABLE XXIX  
Estimated Emissions of Aircraft at Toronto International  
and Washington National Airport

Pollutants	Toronto International Emission (tons/year) 1970	Washington National Emission (tons/year) 1970
Carbon Monoxide	1,100	1,870
Nitrogen Oxides	400	363
Sulfur Dioxide	125	105
Particulates	600	230
Total Hydrocarbons (incl. fuel venting)**	5,300 (87)	400 (120)
Aldehydes	2*	3.7

Data from references 96 and 97.

\*Estimated on basis of emission data for Washington National Airport.

\*\*Fuel venting by departing jet aircraft.

TABLE XXX

Comparison of Activities of Toronto International  
and Washington National Airport (1970 - 1980)

	Arrival / Departure (thousands)					
	Toronto International			Washington National**		
	1971*	1975	1980	1970	1975	1980
Air Carrier	122	130***	140***	220	232	240
General Aviation	76	76	76	110	108	107
Military	1	N.A.	N.A.	3	N.A.	N.A.
Total Passengers	7,250	9,200	16,000	10,100	12,500	15,200

\* Data from reference 95.

\*\* Data from reference 97.

\*\*\* Projections based on data of projected passenger traffic and increasing average number of passengers per carrier.

N.A. Not Available.

except for particulates and HC's. Particulate and hydrocarbon emission estimates are significantly higher for TIA than for WNA which is the result of a different degree of HC and particulate emission control assumed for the calculation of pollutant emission.

Table II compares aircraft emission at TIA with emission of other sources in Metropolitan Toronto. Although the contribution of aircraft to total pollutant emission is minor, pollutants are emitted in a relatively small area and therefore may contribute substantially to the overall pollutant level at TIA.

(i) Impact on the Environment

A survey of the air quality in the vicinity of TIA from November 1968 to November 1969 concluded that aircraft activity during this period was not a major cause of pollution at ground level in either Etobicoke or Peel County.<sup>(98)</sup> It was however, found to be impossible to assess the relative contribution of aircraft to hydrocarbon concentrations in air due to the interference by automotive traffic. Smoke emissions of aircraft, was found to be a source of a large number of citizen's complaints.

In order to get a relative rating of the environmental impact of TIA an attempt is being made to compare TIA

with the impact of WNA which was evaluated in a study based on 1970 aircraft activity.<sup>(97)</sup>

At WNA predicted annual average concentrations for particulates are well within the limits of the Ontario standard. The annual U.S. standards of 0.05 ppm are exceeded several points within the airport boundary by 10 to 90% although emission by aircraft alone would have resulted in values below the standard. The sulfur dioxide ( $\text{SO}_2$ ) standard is exceeded at three locations at the airport boundary with aircraft contributions of only 2%.

More importantly, measured short term maximal concentrations for particulates,  $\text{NO}_x$ , HC's, CO and  $\text{SO}_2$ , exceeded the corresponding standards within the airport boundaries significantly. At the airport boundary the standard for particulates was exceeded at one location, while the corresponding standard for HC's was exceeded at several locations, although the contribution of aircraft to the total HC level was only 6%. The standard for CO was exceeded at one boundary location with 75% aircraft contribution.

In the vicinity of WNA (3 miles from terminal) pre-

dicted annual mean concentrations for particulates,  $\text{NO}_x$  and  $\text{SO}_2$  rarely exceed the corresponding standards. The contribution of aircraft to the overall pollutant level in these areas is minimal, although short term violations of HC standards occur. Thus a maximum HC level of up to 37 times of the desirable level was measured in a location 3 miles north of the main run-way. It is believed that this was a result of fuel venting of jet aircraft over the affected area.

In summary, it may be concluded that at the present time pollutants emitted by aircraft exceed short-term maximal concentration standards within the airport boundaries, but their effect on air quality outside airport boundaries is relatively small. Since the aircraft activity of TIA is approximately 60% of that of WNA, its impact on the air quality of the surrounding environment may be expected to be somewhat smaller, assuming that atmospheric conditions provide an equally good dispersion of emitted pollutants at TIA.

(ii) Aircraft Emission Control

Past actions for the control of gas turbine aircraft engine emissions have been concentrated primarily in the area of smoke reduction since this emission was

the first to be of public concern. Programs for smoke reduction have been initiated by all the major aircraft engine manufacturers.

Smoke reduction has been achieved for several engine models; redesigned combustors that emit only a faint smoke trail are now in commercial service. The net result of these smoke reducing programs has been the establishment of a firm technological base to cope with this pollutant.

In addition to the program for smoke reduction, efforts are underway to obtain a better definition of the nature and extent of the invisible components of jet engine exhaust.

Odors resulting from the operation of aircraft engines are noticeable at airports and are objectionable. Since, at present, the substances causing the odor have not been precisely identified, odor was not explicitly considered in this study. Gas turbines, however, are known to emit aldehydes, which are odorous substances and even at low concentrations, may be irritating to the eyes and to mucous membranes. It is expected, however, that odor reduction will accompany a decrease in the level of HC and aldehyde emissions.

The following conclusions concerning emission control for turbine-engine aircraft were drawn:<sup>(97)</sup>

- (1) Minor modifications of combustion chambers provides large reductions in HC and particulate emission, and a lesser reduction in CO emission.
- (2) Minor modifications in ground operating procedures will further reduce CO and HC emissions, but will increase particulate emission.

For piston-engine aircraft control devices developed for automobile engines could produce large reductions in CO and HC emissions. These devices may require low-lead gasoline thereby reducing lead concentrations as well.

Theoretical studies have been made which show that of all the exhaust pollutants, oxides of nitrogen present the greatest control problem. Although the phenomena of formation of this exhaust emission product are understood, a firm technology for its reduction in actual engine combustion systems does not exist as yet.<sup>(99)</sup>

Air Canada and CP Air are spending about \$3.5

million to reduce polluting emissions from jet engines by about 1972.

(iii) Future Impacts of Air-Carrier Airports

Considering increasing aircraft activity, the change in total population of each aircraft class and increasingly better emission controls, the following general trends for aircraft emission at air-carrier airports are predicted by Northern Research and Engineering Corporation during the next decade.<sup>(90)</sup>:

- (1) A small increase in total particulate emission of approximately 20%.
- (2) A small increase of  $\text{SO}_2$  emission of approximately 30%.
- (3) A large increase in  $\text{NO}_x$  emission of approximately 200%.
- (4) A small decrease of CO emission of approximately 10%.
- (5) A large decrease of HC emission of approximately 60%.

5.2.2 Water Pollution

Oil, grease and other hydrocarbons drop from vehicles onto the streets and roads can be washed into the waterways by rain and cleaning operations. Its impact on the water quality has not been measured but is not felt to be serious.

However, the increasing use of salt as a deicing agent has, in the past years, raised many questions as to the effect of chlorides from this source on water quality.

The practice of snow disposal into lakes and rivers is common in many municipalities. This is considered a convenient and economic means of snow disposal.

Recent analysis of a snow disposal site indicates that snow scraped from roads may contain high concentrations of suspended solids, organic material, phosphorus, chlorides and lead introduced through automobile exhaust. Visible pollutants such as oil, trash, soil and soot are readily evident. Following the spring thaw, materials contained in the snow are introduced directly to the watercourse and may cause seriously degraded water quality. With controls such as covered sand-salt stock piles, limiting the use of deicing salt and restricting snow dumping to land sites wherever possible, significant sources of water pollution can be substantially reduced.

#### 5.2.3 Impact on Land

Vehicles abandoned by their owners is decreasing the aesthetic value of private and public land rather than being a pollution problem. At present the number of derelict vehicles across Ontario is estimated to be about 750,000. Recently a survey was initiated to identify areas of

high derelict vehicle density in order to show where a full-scale clean-up program is needed. The survey is designed to further reveal the economic potential of scrap metal recycling in any given area and also the attitude and receptiveness of people in a given area.

The Waste Management Branch pointed out that the successful completion of a major clean-up project would help to keep Ontario beautiful and in addition reduce the depletion of raw material.

#### 5.2.4 Noise Pollution

Noise is a by-product of all fuel-burning transportation devices. The background noise level of any large urban area of 45 to 50 dB(A) is principally due to the noise generated by the thousands of vehicles travelling about the area (Figure 24). Community noise is being regarded as an environmental pollutant by an increasing number of people and the Ontario Environmental Protection Act, 1971 recognizes it as such. Figures 25 and 26 summarize the noise levels in a statistical manner from a wide variety and type of vehicles. The Federal Department of Transportation will be placing limits on the permissible noise levels of new vehicles at:

Automobiles and Small Trucks	83 dB(A)
Large Trucks	87 dB(A)
Motorcycles	83 dB(A)

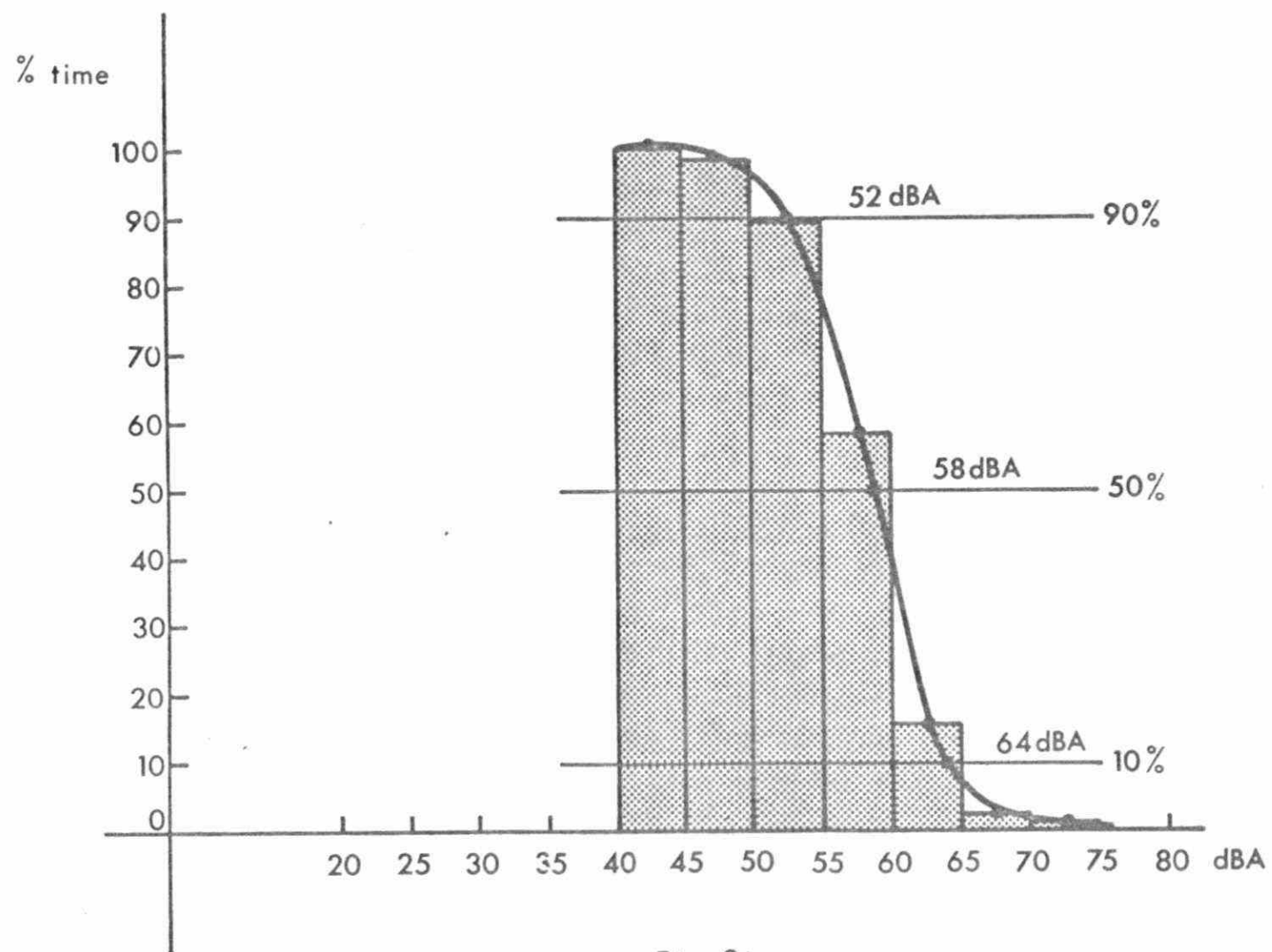


Fig. 24

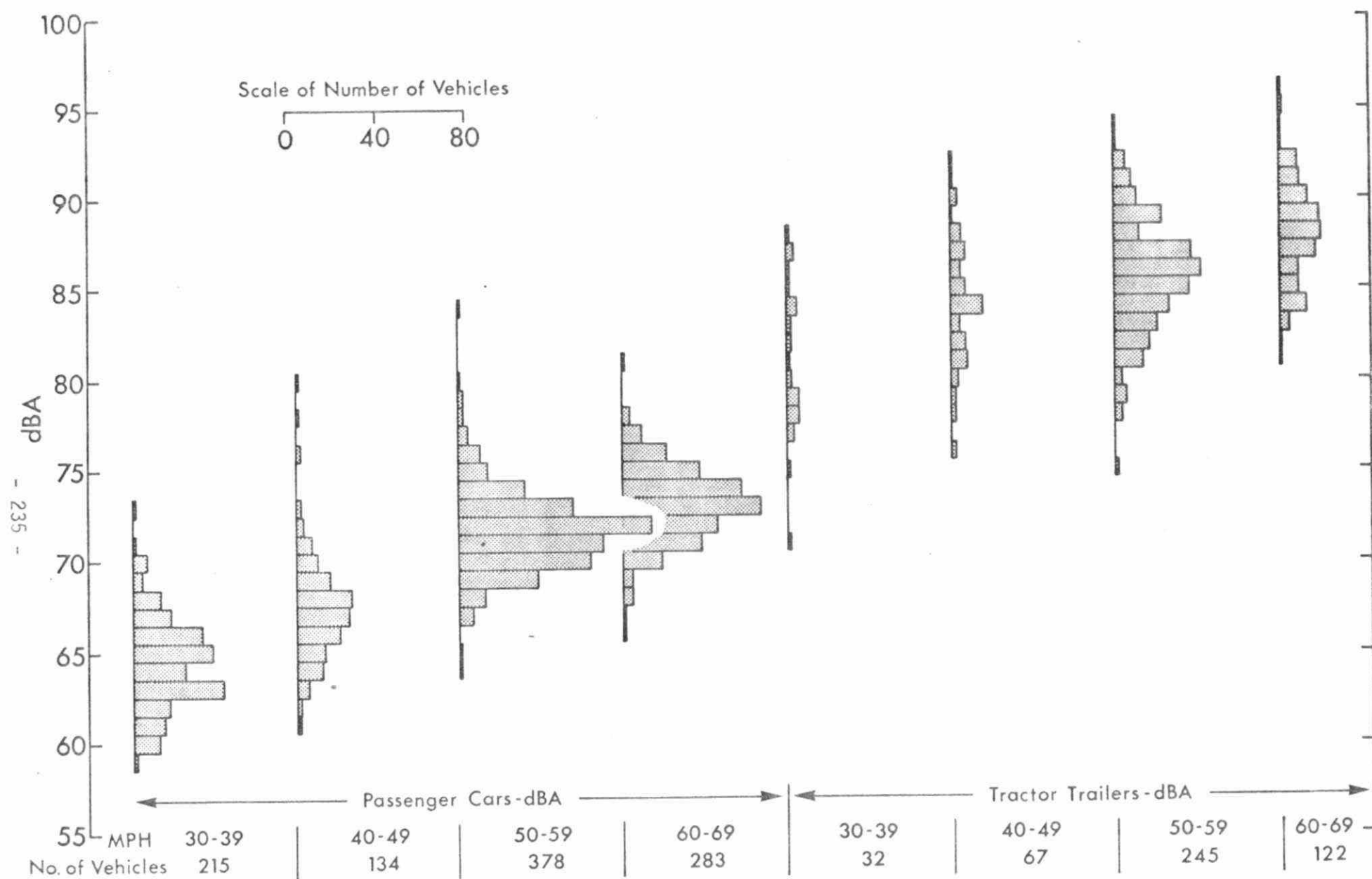


Fig. 25

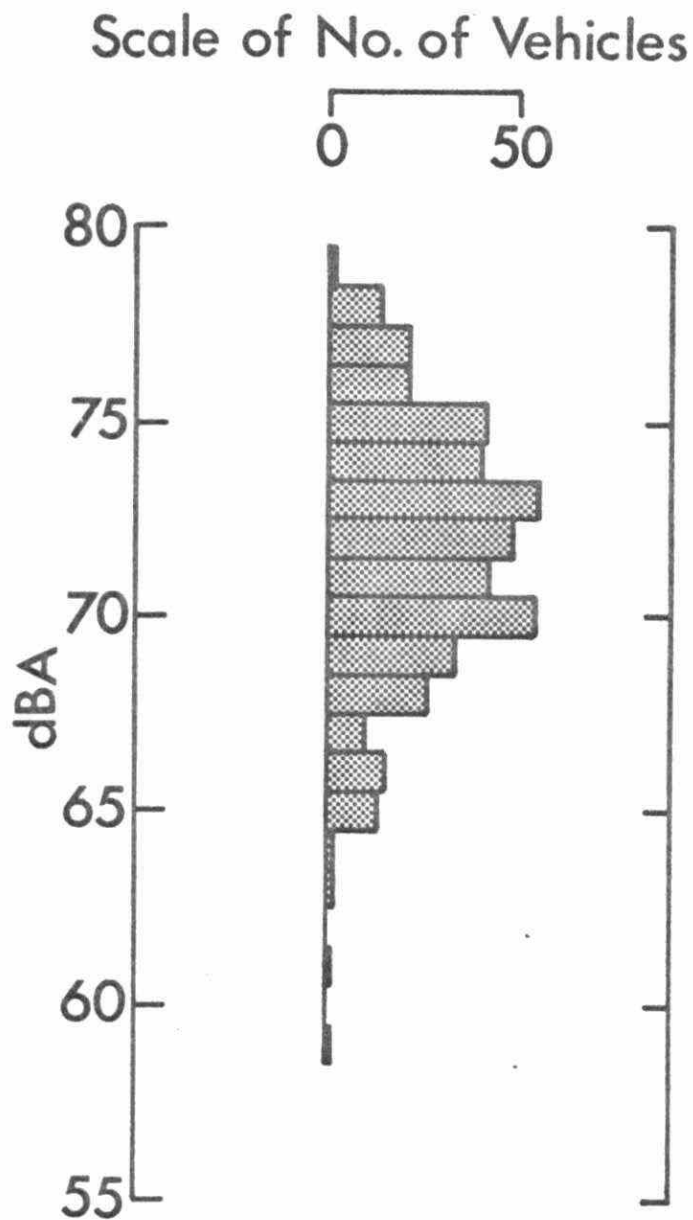


Fig. 26 Buses: Ottawa Transport Commission, accelerating at low road speed (0-20 mph), 441 readings on 128 vehicles, A weighting only.

This, in effect, will limit the noise potential of future vehicles. However, comparison with Figures 24 and 26 illustrate that it will not reduce community noise levels appreciably inasmuch as vehicles rarely operate at their noise potential. The Ontario Ministry of the Environment has suggested to the Federal Government that a staged reduction of these noise levels be considered in the future.

Noise levels in all communities may be expected to increase in the future as the population of vehicles increases. Moreover, the serious noise problems adjacent to freeways busy streets, stop-and-go truck routes and airports will also increase. Noise levels adjacent to freeways may reach a steady 80dB(A), an accelerating truck can produce over 100 dB(A), and around airports intermittent levels up to 110 dB(A) are not uncommon. Under the Ontario Environmental Protection Act, 1971, noise can be controlled by the Province. Noise regulations are being devised and drafted to implement this aspect of the Act. Recently standards have been proposed in the U.S. to identify those areas of land in the vicinity of highway projects which are sensitive to noise and to compute the expected highway noise levels in these areas on basis of the worst noise situation expected to occur. Where anticipated highway noise levels exceed the design noise levels, corrective

measures are to be taken to the extent feasible. For residential areas and schools the design noise level is 70 dB(A) not to be exceeded more than 10% of the time during the worst hour of the day. (100)

It is clear that implementation of a 70 dB(A) standard in residential areas will call for substantial noise abatement measures on new highway projects. Existing noise barriers along major highways in the Toronto Metropolitan area were reported to have little effect. (101) Therefore, it is important to limit the noise emission of future vehicles as has been suggested to the federal government.

Also, land-use planning in the vicinity of airports, freeways and at other significant noise sources must be much more effectively controlled in the future. In addition, rapid mass transportation systems designed with low noise levels in mind can effectively reduce urban noise levels.

#### 5.2.5 Land Use

##### 5.2.5.1 Mass Transportation

The noise and air pollutants caused by automobile emissions are a major problem in congested urban areas. Even with future legislative controls for cleaner engines an alternative to inter-and intra-urban travel should be provided

if we are to ensure a healthy urban environment since the increasing number of cars may negate the effectiveness of legislation designed for an acceptable quality of air.

One of the greatest energy inefficiencies in modern society is the transportation of people in cities, since the automobile is the least efficient means of urban transportation and is by far the greatest user of energy (See Table XXXI and XXXII).

About 82% of all energy used for urban transportation per year in the U.S. in the mid-1960's was used in private automobiles and, of that, 60% was used in trips of less than 2.5 miles. This disproportionate use of private automobiles has continued unchallenged despite the gross inefficiency and the serious contribution which automobiles make to pollution.

Origin-destination studies show that the bulk of urban automotive travel is the morning and evening journey to and from work. Therefore, it may be concluded that if the morning and evening rush-hour congestion can be alleviated by an alternative more efficient and cleaner mode of transit, there would be a significant reduction of air pollution.

TABLE XXXI

Efficiency of Various Means of Urban Transportation\*

Vehicle	Net Propulsion Efficiency (passenger miles/gal. or energy equivalent)
Electric Trains	75 - 100
Bus	100
Automobile (Average)	30 - 40
Automobile (1 Person)	17
Motorcycle	160

\* Data from reference 102.

TABLE XXXII

Total Energy Consumption for Urban Transportation U.S. Annual Mid 1960's\*

Vehicle	Energy Used (millions of gallons)
Trains	70
Buses, Taxis, Limousines	400
Private Autos - trips of more than 2.5 miles	14,000
- trips of less than 2.5 miles	21,000
Trucks and Parcel Delivery	5,400
Institutional Vehicles	<u>1,800</u>
Total	42,670

A study conducted in Metropolitan Toronto revealed that in 1970 about 69% of the population was using public transportation during the rush hour periods to the downtown city core area (Table XXXIII). This compares favourably with earlier 1960 data when 57% were using public transportation.

Metropolitan Toronto early realized the need to promote a rapid transit system to relieve congestion and to reduce air pollution. For a transit system to be accepted it must be commuter oriented, i.e. it must be fast, efficient, convenient and cheap. Also, the effectiveness of a rapid transit system is largely dependent on the availability of an extensive surface transit network and adequate free terminal parking.

One of the arguments against promoting rapid transit is based purely on cost. There have been, to date, few cost-benefit analyses carried out comparing rapid transit against roadway and expressway type transit. Subway construction and maintenance is undeniably expensive. For this reason, surface rapid transit should be entertained. On-surface transit can be less expensive, more far-reaching and much quicker to implement. The problem of rights-of-way can be overcome by developing the "multi-functional corridors." Criss-crossed throughout most large urban

TABLE XXXIII

Public vs. Private Transportation to Down-town Toronto\*

Year	% of population using TTC and Go-system		% of population using private means of transportation	
	Peak Rush Hrs.	All Day Average	Peak Rush Hrs.	All Day Averages
1960	57	50	43	50
1970	69	50	31	50
1971	70	50	30	50

\* Information obtained from Mr. S. J. Sanson, Director  
of Metropolitan Roads and Traffic Department.

centres are a series of hydro easements, railway lines and expressways. Since these easements already exist and may be wide enough to accommodate a transit line, all that is needed are some buffer strips to cut down noise and add some aesthetics. Research is presently being carried out to test the effectiveness of rubber wheels for commuter-type trains. If they prove successful, noise will be greatly reduced. With the growth of and encouragement for satellite urban communities, development of intra urban transit by commuter lines would be extremely valuable.

The concept of using existing utility easements to evolve a system of inter- and intra-urban mass transportation is not new. Numerous urban areas in the U.S. have had consulting firms analyze the problem and prepare concept reports. Few proposals have been implemented, either because of initial costs or because politicians are not convinced that a system other than the private automobile is needed. Doxiadus Associates published a three-volume report on "Emergence and Growth of an Urban Region - Detroit." The report envisages the use for alternate modes of inter and intra urban travel if we are to ensure a healthy urban environment. Doxiadus predicts the need by the year 2000 of dual mode electric urbmobiles which can operate automatically on high-speed guideways and also

manually on urban streets; even though the idea today seems far-fetched, it does indicate that there is a need to rethink the urban transportation problem. Doxiadis also discussed the need to utilize existing rights-of-way and to turn them into multi-functional corridors.

The proposed official plan for Metropolitan Toronto, provides for transportation corridors combining express-way with rapid transit. There are two major hydro easements (approximately 100 feet wide) radiating in an easterly and westerly direction from the centre. Also, there are a number of Canadian Pacific and Canadian National rail lines crossing through the city. If these rights-of-way were combined; their existing function with rapid transit lines coupled with 'bus feeder' lines, the Metro Region could have a very effective inter and intra urban transit system without exorbitant costs.

The above citation is for the Toronto Region. A similar picture can be seen for cities like Hamilton, London and Ottawa.

In order to promote public transit over urban automobile travel, it will be necessary for the government to review and alter the grant system for the large urban areas where

automobile congestion is an urgent problem. Presently, the grant system favours highway development and maintenance. In the defined urban areas, grants should be given for transit development and maintenance. Terminal parking should be adequate and included in the ticket cost. The transit system must be ultimately cheaper, faster, more efficient and convenient to the user than the use of his own automobile. In this manner it would be hoped to further increase the percentage home-work travellers using public transit systems.

### 5.3 Impact of Industrial Consumption of Energy

In 1970 industry accounted for about 35% of the total energy consumed in Ontario (See Table XVIII). Although the relative energy consumption is expected to decrease slightly by 1990 the total energy demand will increase approximately 2.5-fold during this period. Presently, coal provides the largest energy supply for the industrial sector followed by gas and oil (Table XXXIV).

Industrial uses of coal, oil and gas are predominantly for the production of coke for the metallurgical industry, generation of steam and electrical power, and production of synthetic gases for chemical processes. Due to the complexity of many industrial operations it is difficult to assess the environmental impact which is attributable to the utilization of energy by industry. Most of the industrial emissions into the air come from a wide variety of manufacturing processes which are not a direct result of energy consumption per se.

#### 5.3.1 Present Air Quality

The main atmospheric pollutants resulting from industrial energy consumption are sulfur dioxide, particulates and nitrogen oxides. The sulfur dioxide and particulate emission depends largely on the sulfur and ash content of the fuels used. The oxides of nitrogen are formed during the combustion of fuels with air. Many industrial operations are aggregated in areas of high pollu-

T A B L E XXXIV

ESTIMATED INDUSTRIAL PRIMARY ENERGY CONSUMPTION  
BY FUEL TYPE FOR ONTARIO\*

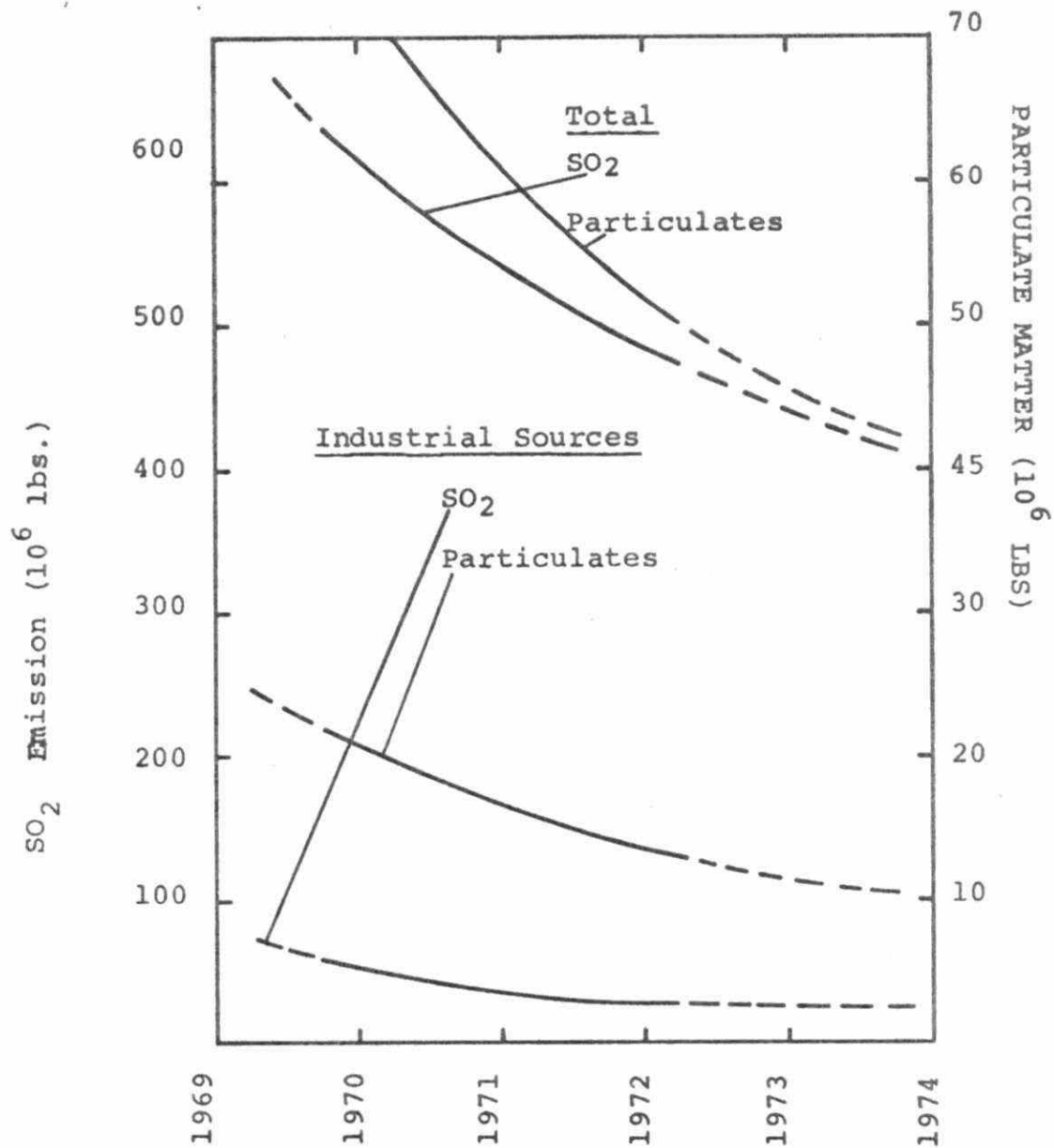
FUEL TYPE	CONSUMPTION ( $10^{12}$ BTU) (In Brackets: percentages of Total)		
	1970	1980	1990
Coal	257 ( 42)	243 ( 24)	230 ( 15)
Oil	133 ( 21)	280 ( 28)	525 ( 34)
Gas	226 ( 37)	490 ( 49)	790 ( 51)
Total	616 (100)	1013 (100)	1545 (100)

\* Excluding electrical energy. Data from references 103 and 104.

lation density such as Toronto, Hamilton and Windsor. Table II summarizes pollutants emitted by the existing broad mix of industrial sources in Metropolitan Toronto. The Ontario Ambient Air Criteria for  $\text{NO}_x$  and  $\text{SO}_2$  and particulate matters were exceeded in Metropolitan Toronto on a number of occasions in 1970 and 1971. While  $\text{SO}_2$  and  $\text{NO}_x$  emissions by industrial sources were somewhat lower than emissions by residential sources, particulate emissions were higher. This most likely is a result of the overall process operations rather than of the energy use alone. Since in Metropolitan Toronto residential  $\text{SO}_2$  and  $\text{NO}_x$  emissions alone were not found to exceed Ontario Ambient Air Criteria at present it is reasonable to assume that a similar situation exists for industrial  $\text{SO}_2$  and  $\text{NO}_x$  emissions. In Metropolitan Toronto an abatement program of increasingly stricter emission controls for particulate matter and limitations of the maximal permissible sulfur content of fuels resulted in a significant reduction of these pollutants during the past few years (Figure 27). These emissions are expected to drop even further as a result of existing abatement programs. However, emissions of oxides of nitrogen by industrial sources are expected to increase and ambient air criteria for  $\text{NO}_x$  may be reached or exceeded in Toronto before 1990 by industrial sources alone.

It should be pointed out that the impact of industrial energy consumption is greatly different in various regions of the

Figure 27 - Sulfur dioxide and particulate emission in Metropolitan Toronto



Province due to the different pattern of primary energy consumption inherent to prevalent local industrial operations. For example, about 80% of the coal is consumed by the metallurgical industry which is concentrated in a few areas. Therefore, sulfur dioxide emitted from steel mills, foundries, coking operations etc. has a significant impact on the air quality. In Ontario this applies chiefly to the Windsor Hamilton, Sudbury, Sault Ste. Marie areas, which are densely populated and are highly industrialized. Table XXXV summarizes the consumption of coal and associated sulfur dioxide emissions by industrial sources and compares it with the main consumer of coal, i.e. the electrical utilities. The metallurgical industry, and in particular the steel industry with associated coke oven operations is second only to electrical utilities in  $SO_2$  emissions. As a result, Ontario  $SO_2$  criteria for ambient air were frequently surpassed in steel production centers in 1970.

It is not possible to relate particulate emission by industrial sources to the consumption of energy, since particulate emission by many industries are mainly a result of their process operations. However, total particulate emissions of large operations are strictly controlled by the Ministry of the Environment. Particulate emission from small coal-and oil-fired installations is not as well controlled. If further improvement of air quality is required the most practical abatement strategy for such

T A B L E XXXV

ONARIO COAL CONSUMPTION AND ASSOCIATED  
SULFUR DIOXIDE EMISSIONS BY MAIN CONSUMERS IN 1970

	Metallurgical Industry	Electric Utilities	Other Industries	Total
Coal Consumption ( $10^6$ tons)	7.8	9.3	2.2	19.3
Equivalent BTU ( $10^{12}$ )	195	234	62	491
Sulfur content (%)	2	2.4	1.5 - 2.5	-
Sulfur content of coal ( $10^4$ tons)	15.6	22.4	4.4	42.4
Potential SO <sub>2</sub> emission ( $10^4$ tons)	31.2	44.8	8.8	84.8

Data from reference 103 and AMB estimates.

industries is a change-over to clean fuels such as natural gas.

#### 5.3.2 Future Air Quality

Industrial energy demand is increasing sharply and by 1990 will be about 2.5-fold higher than today. Also the distribution pattern of prime energy consumption is expected to change significantly (Table XXXIV). Coal consumption is expected to decrease somewhat during the next two decades. This is the result of the replacement of the fuel gas heated open hearth furnaces with basic oxygen furnaces by the steel industry. The BOF requires less fossil-fuel energy than the open hearth furnace. It is fed with oxygen instead of air whereby the heat losses of the nitrogen from the air are avoided and some iron metal oxidation contributes a certain amount of non-fossil-fuel energy to the process. As a result the sulfur dioxide emission in steel producing centres may be expected to decrease slightly.

Oil and gas consumption, on the other hand, will increase significantly. While natural gas is the most desirable energy source from an environmental viewpoint, its long-term supply situation is uncertain. Therefore, the use of natural gas by industries should be controlled so that adequate supplies are available in the future where it is necessary for the process operation or where no other air pollution abatement method is feasible. The policy of restricted usage of natural gas may be revised in some

distant future, when coal gasification will provide a long-range supply of clean fuels. However, coal gasification is still at least one decade away and many technical problems have yet to be resolved (See Section III/5.1, Desulfurization of Fuels).

The consumption of oil is associated with similar environmental problems as the consumption of coal. Of prime concern is the sulfur content of oil which may vary over a wide range. The expected increase in oil consumption may require restrictions of the maximal permissible sulfur content of the oil products used in a particular area in order to provide a good air quality. Since control technology for particulate abatement and desulfurization of oil is available provincial air-quality standards will be met in the future.

At present, however, there is no technology existent to abate  $\text{NO}_x$  emissions. As a result,  $\text{NO}_x$  emissions are expected to increase in accordance with the increase of fuel consumption and provincial  $\text{NO}_x$  criteria will be exceeded more frequently in wider and wider areas. Ultimately, a limit to industrial growth for selected areas may have to be considered in order to assure an acceptable quality of air.

#### 5.3.3 Water Quality

The consumption of coal and oil for generation of steam or electrical energy results in water quality problems similar to those

of the generation of electrical power from these fuels, but on a smaller scale. Coke production from coal creates a variety of water quality problems due to discharge of phenols, ammonia, sulfides and other compounds. In addition, the quality of the water may be decreased by increasing the chemical oxygen demand through the discharge of waste streams.

#### 5.3.4 Conservation and Improvement of the Environment

Since the manufacturing process of all products consumes energy, there is a certain amount of pollutant emission associated with each individual product or service produced. In addition, many products cause more pollution problems when they eventually end up in incinerators, landfills or are disposed of in unacceptable ways. Therefore, conservation of energy and non-renewable resources may potentially reduce pollution caused by many manufacturing and industrial sources. Basically, conservation involves the reuse of products and resources, recycling of waste products and the manufacturing of products of increased durability.

On the basis of consumed energy, it has been shown that non-returnable containers are more energy-expensive than returnable ones.<sup>(105)</sup> The use of returnable containers would not only conserve a significant amount of energy but would benefit the consumer additionally by reducing costs and by alleviating the pollution created by discarded containers. There are several

means of encouraging the use of returnable containers.

The amount of energy used in production of metals varies greatly depending on the type of process used for purification. The reclaiming of some metals, such as aluminum, copper, and titanium, is considerably less energy-expensive than obtaining them from raw ores. (106)

Although exact figures for the energy expenditures for producing paper from pulp and from scrap paper are not available, it appears that recycled paper is less energy-expensive than virgin paper. It was estimated that in the U.S. the savings on disposal cost alone of recyclable newsprint and paperboard is in the order of \$200 million. (107)

Present tax policies provide economic encouragement for continued and expanded use of primary or virgin products. Tax policies should be reexamined and consideration given to changes that would:

- (a) provide manufacturers with a realistic incentive factor for utilizing more recycled materials through a recycling tax deduction or credit,
- (b) encourage new and expanded plant investment in recycling facilities and equipment through rapid write-off and amortization of such investments,
- (c) provide a basis for expanding research and development activities by industrial firms capable of recovering recycled materials.

One of the major inefficiencies in our society is the rapid turnover of consumer goods. The rapid obsolescence of goods is frequently planned by the manufacturing industry in order to increase sales.

Substantial improvement in energy efficiency could be achieved if industry made an honest effort to increase the life expectancy of its products. Tax policies should be designed and implemented to encourage industry to increase the durability of its products.

Impact of Residential and Commercial Uses of Energy

Residential and commercial uses accounted for about 30% of the total primary energy consumption in Ontario in 1970 (See Table XVIII) and for about 45% of the electrical energy consumption. The percentage of primary energy consumption is expected to decrease to 19% by 1990, but the absolute consumption of energy will increase from  $537 \times 10^{12}$  BTU to  $984 \times 10^{12}$  BTU during the same period. In order to evaluate environmental problems attendant to energy use for these purposes, the present and projected residential and commercial energy consumption by fuel type as shown in Table XXXVI has been employed. In the household, the major consumption of energy is for space heating, followed by lighting, water heating, stove, refrigerator, freezer, air conditioner, and other uses. Commercial uses are predominantly for space heating and lighting. In assessing the environmental impact of these energy uses only the direct consumption of fossil fuels is considered, since the environmental impact of generation and use of electrical energy has been covered in a previous section of this report.

Some comparisons will be made, however, between fossil fuel and electrical heating systems, and some methods of conservation of energy by residential and commercial consumers will be

TABLE XXXVI

ESTIMATED RESIDENTIAL AND COMMERCIAL PRIMARY ENERGY  
CONSUMPTION BY FUEL TYPE FOR ONTARIO\*

FUEL TYPE	CONSUMPTION ( $10^{12}$ BTU) (In Brackets: percentages of total)		
	1970	1980	1990
Coal	21 ( 4)	7 ( 1)	2 ( 0.)
Oil	319 ( 59)	397 ( 53)	483 ( 49 )
Gas	188 ( 35)	333 ( 45)	496 ( 51 )
Other	9 ( 2)	6 ( 1)	3 ( 0.)
Total	537 (100)	743 (100)	984 (100)

\* Excluding electrical energy

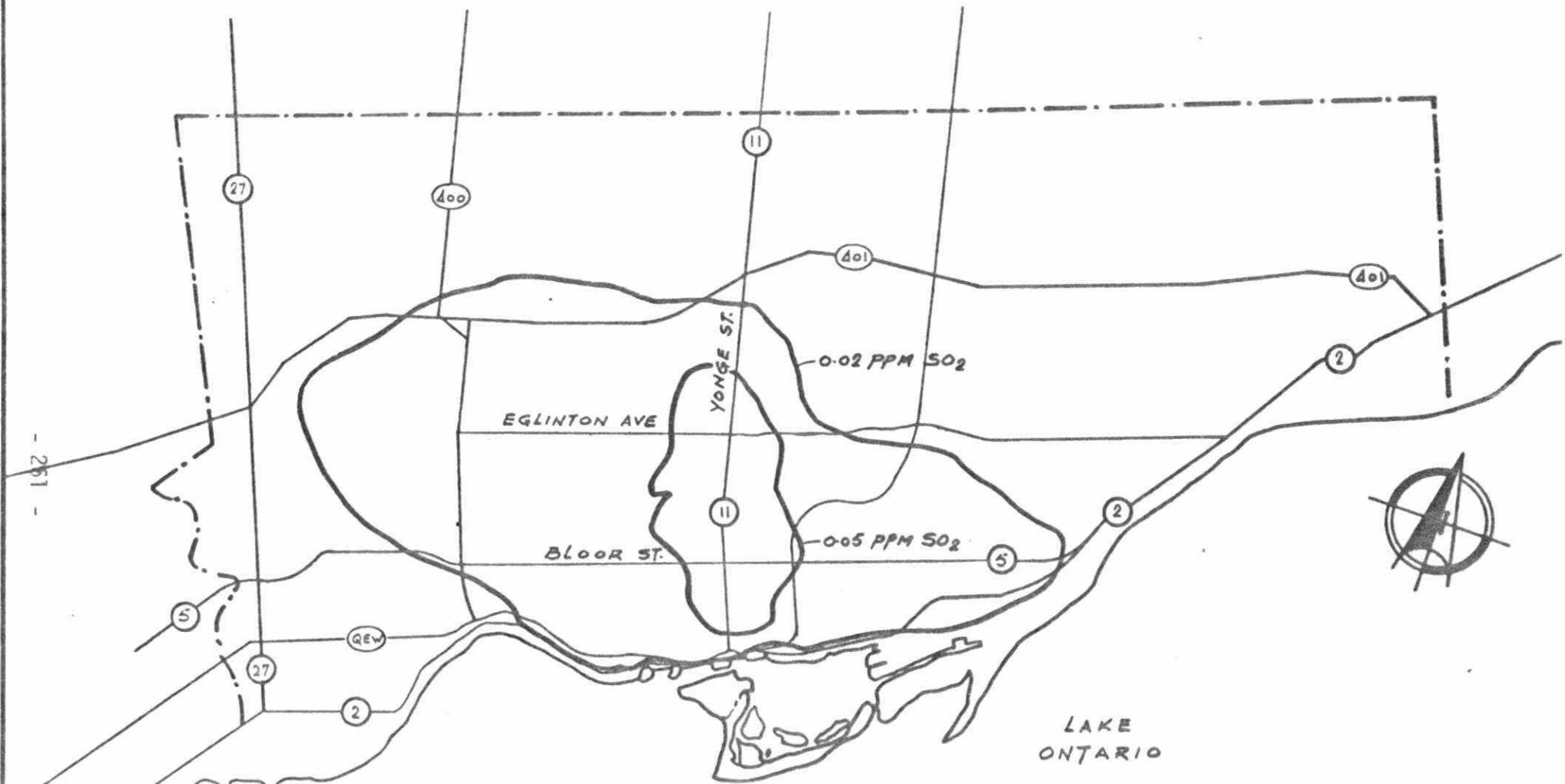
discussed.

#### 5.4.1 Air Quality

In Ontario the highest density of residential and commercial developments doubtless exists in Metropolitan Toronto. Consequently, pollution problems due to commercial and residential sources may be expected to be most evident in this area. Table II summarizes pollutants emitted by residential and commercial sources in Metropolitan Toronto. The Ontario Ambient Air Criteria for  $\text{NO}_x$ ,  $\text{SO}_2$ , CO and suspended particulate matter were exceeded on a number of occasions in Metropolitan Toronto in 1971 and emissions from residential and commercial sources contributed towards this. Mathematical modelling of the residential and commercial emission only (discounting all other sources) indicated that even under the most severe meteorological conditions, they alone cannot at the present time cause the Ontario Ambient Air Criteria to be exceeded. As shown in Figure 28, the maximal  $\text{SO}_2$  concentration in a large urban area due to residential and commercial sources may reach about 0.05 ppm or about a quarter of the permissible limit.

If it becomes desirable to reduce  $\text{SO}_2$  emissions from residential and commercial sources, the use of low-sulfur fuel is the best  $\text{SO}_2$  abatement strategy for these hundreds of thousands of air pollution sources. The increasing use of gas and low-sulfur oil in these applications has already resulted in better air quality. Table XXXVI illustrates that some additional improve-

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METROPOLITAN TORONTO  
1970 AIR QUALITY DUE TO RESIDENTIAL & COMMERCIAL EMISSIONS  
SULPHUR DIOXIDE (IN PARTS PER MILLION)

SCALE 1" = 2.6 MILE

ment can be made with respect to  $\text{SO}_2$  emission by displacing coal of a relatively high sulfur content with gas and to a lesser degree with oil. At present, the larger power generation and industrial sources employ equipment to remove particulate matter and are required to erect stacks so that pollutants are diluted before reaching ground levels. However, flue-gas cleaning abatement systems are not practical for residential and many commercial sources. It should be recognized, however, that residential and commercial sources provide the overall urban background levels of several air pollutants. Since it is not economically feasible to abate small residential and commercial sources within the foreseeable future, low-sulfur fuels should be reserved for these uses. The need to abate pollutant emission by large sources such as fossil-fuel electrical generating station, industrial boilers, industrial processes, etc. may be dictated by the pollutant levels that residential sources unavoidably produce at present as shown in Figure 29.

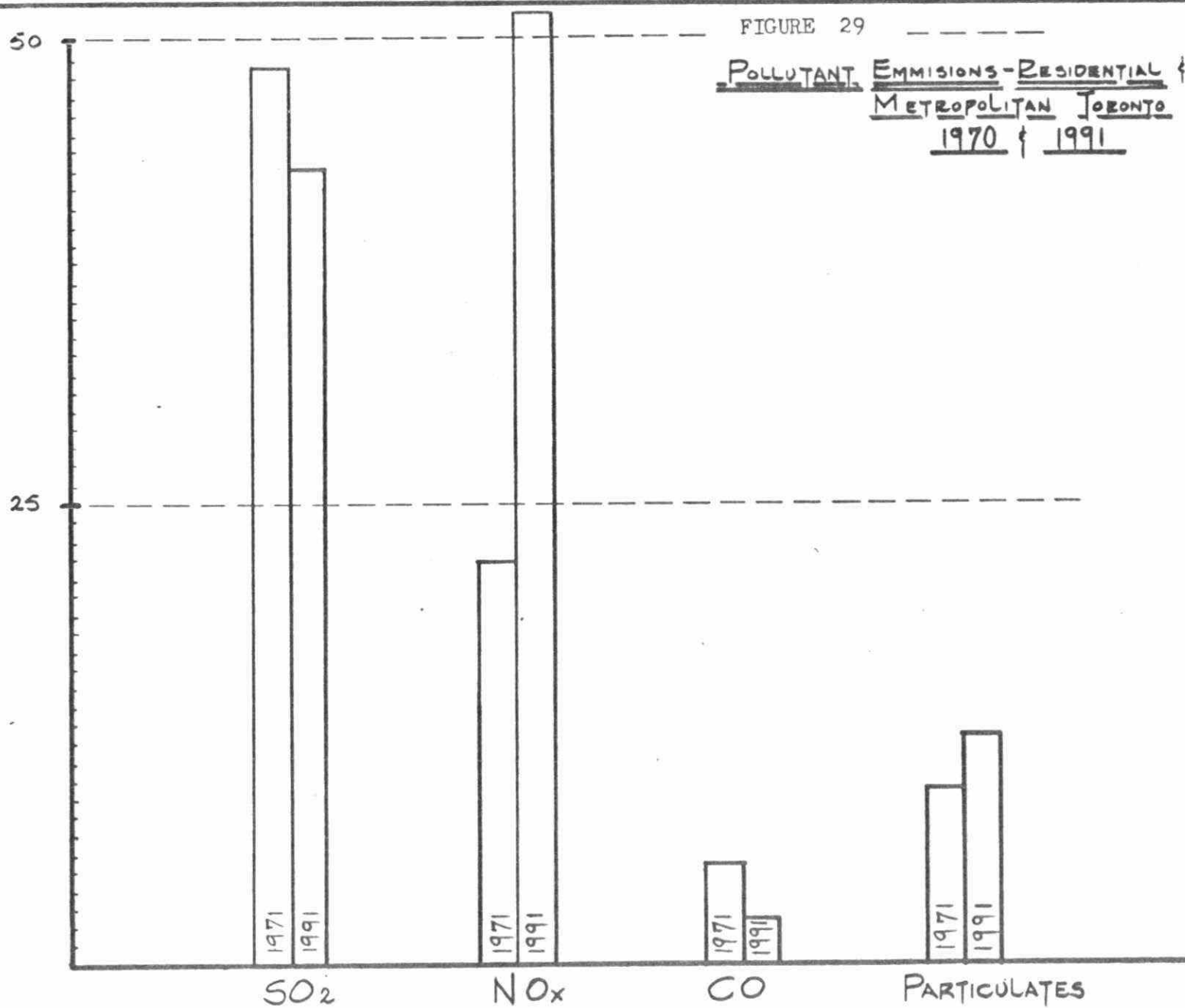
It is anticipated that the population of Ontario will continue to grow to the figures shown in Table XVII, while the total primary energy consumption for residential and commercial uses will increase by about 83% during the next two decades. Based on the expected growth of energy consumption and change in fuel pattern, pollutant emissions for 1990 were estimated for Metropolitan Toronto and are compared with 1971 values in Figure 29.

EMISSIONS  
(LBS/YR  $\times 10^6$ )

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FIGURE 29

POLLUTANT   EMISSIONS - RESIDENTIAL & COMMERCIAL  
METROPOLITAN TORONTO  
1970 & 1991



Due to changing patterns in fuel consumption the total emission of  $\text{SO}_2$  is expected to decrease slightly. However,  $\text{NO}_x$  emission is expected to double as the energy demand increase. As a result,  $\text{NO}_x$  criteria of ambient air may be reached or exceeded in Toronto before 1990 by residential and commercial emission sources alone.

In order to reduce air pollution from a residential and commercial sources, several conservation strategies are available, such as:

- (1) Improved insulation of building.
- (2) Improved efficiency of heating systems.

Space heating is achieved either by direct use of fuels in a home furnace or by use of electricity. Most heating in Ontario involves direct use of fossil fuels but electric heating has been gaining popularity. Insulation is a major factor in determining the amount of energy needed to heat a building and consequently indirectly affects the amount of pollutant emission. Houses designed for electrical heating are, in general, much better insulated in order that this heating method can be economically competitive. If similar insulating standards were adopted in homes using direct fossil-fuel heating, the energy saving would be considerable. However, at present the economics of initial cost appears to be the deciding factor against improved insulation. The efficiency of the home heating system is not as closely supervised as that in large industrial

installations. Better design and system maintenance will potentially reduce pollutant emission. The need for a better conservation of fuel together with a reduction of pollutant emission may necessitate a closer check into the efficiency of residential and commercial heating installations.

#### 5.4.2 Electrical Heating

Electrical space and water heating for residential and commercial buildings appears to be a convenient, clean method of heating. However, a closer examination of relevant facts reveals that the prime energy resource is not utilized as efficiently. The energy conversion efficiency of thermal generating stations (35-40%) is notably lower than the efficiency of household furnaces (55-75%). As a result, thermal generating stations emit larger quantities of pollutants to the atmosphere than does the direct use of oil or gas. Table XXXVI shows the estimated emissions caused by the heating of an average home. The figures for electric heating represent pollutants emitted at the generating station with the existing mix of power generation sources (i.e. water power, oil, coal and nuclear). Power plant emissions are generally discharged several hundred feet above the ground while home furnace emissions are released close to the ground.

While many factors influence the environmental impact of heating methods it is undoubtedly easier to control the emissions from large central plants than it is from numerous small homes.

Also, the values given in Table XXXVII for direct burning of fuels in home furnaces are for ideal conditions. Undoubtedly, many furnaces are poorly serviced and improperly adjusted and consequently may release much greater quantities of pollutants.

However, considering all aspects of this problem it appears that electrical residential or commercial heating at present is less desirable from an environmental standpoint. Until coal-or oil-fired power plants install flue-gas abatement systems for  $\text{SO}_2$  and  $\text{NO}_x$ ; or, until nuclear power generation is a much larger portion of the overall capacity, electrical home and commercial heating should not be encouraged. However, urban air quality could be significantly improved in the future by displacing residential fossil-fuel heating with electrical heating, if (1) power plants are isolated from urban areas, (2) flue-gas abatement systems are routinely employed and (3) the nuclear capacity increases. These paths should be encouraged with the result that electrical heating could be environmentally very desirable in the early 1980's.

#### 5.4.3 Other Uses of Electrical Energy and Conservation

The major residential uses for electrical energy are lighting, water heaters, stoves, refrigerators, freezers, and air conditioners, each unit using more than 1000 kwh per year and cumulatively using 75% of total household use. Water

TABLE XXXVII

AIR POLLUTANTS EMITTED IN THE HEATING OF  
AN AVERAGE HOME - LBS/YEAR

	Gas Furnace	Oil Furnace	Electric Heating*
SO <sub>2</sub>	0.1	68.0	380.0
Particulate	3.2	12.0	7.4
NO <sub>x</sub>	8.5-17	14.4	93.9

\*Based on 1971 estimate of power generation mix of 41% by coal, 3% by gas, 50% by water, and 6% by nuclear.

heaters have the highest energy demand of any appliance, using over 4000 kwh per year. Gas water heaters use only half as much fuel energy as electric water heaters and widespread use of gas for water heating would represent a major reduction in energy demand. Similarly, gas stoves could replace electric ranges but the total energy conserved would not be as great as for water heaters. The question of excessive lighting of buildings on a 24-hour basis should be considered from the effect upon the environment and also from the aspect of the availability of fuel to generate electricity. One private power company in the U.S. reduced its energy demand by 1 to 2% by advertising conservation. This saving in energy represents perhaps a 20% reduction of the mean yearly growth demand of 7% per year.

The use of waste heat from thermal power stations and other boiler installation is often mentioned as an energy resource for area heating. This is not practicable with existing systems, but it is a possibility in the design of a self-contained total energy system in new towns or large buildings. This idea should be part of future design concepts.

#### 5.4.4 Water Pollution and Land Use

The utilization of fossil fuels in residential and commercial applications does not give rise to direct water quality problems, waste disposal problems or other factors affecting land

use and resources.

#### 5.5 Impact of Energy Use by Recreational Vehicles

The use of energy in recreational pursuits is increasing each year. Primarily gasoline is used to power a variety of motorized equipment. Although recreational devices account only for a very small fraction of the total energy used in Ontario, they create environmental impacts far beyond the problems associated with the consumption of energy. These problems will increase in the next two decades due to the increase of leisure time and resources the public will have for recreational pursuits. In many cases problems are created by persons using these devices in an inconsiderate and irresponsible manner.

##### 5.5.1 Snowmobiles

A total of 113,289 snowmobiles were registered in Ontario up to 1971, providing an average of 155 hours of snowmobiling per user during the season. (108)

Snowmobiling is growing fast in popularity with an annual increase of snowmobiles of 30,000. The sport is generating a sizeable economic activity both in recreational areas formerly based on a summer season only and in the manufacturing centres of these vehicles. However, snowmobiling has resulted in adverse environmental impacts including noise, property damage and trespass, pollutant emissions, littering,

disruption of wildlife, damage to plants and soil, as well as injuries and fatalities to people. In order to control the environmental impacts from the recreational use of snowmobiles, a restriction of their use to selected designated areas and trails is recommended.

Table XXXVIII indicates the snow compaction effect by snowmobiles. A four-fold increase of thermal conductivity by two snowmobile passes illustrates how the insulation effect of snow is destroyed by compaction. Snow compaction may result in lowering of soil temperatures and deep freezing which can affect the survival of many species by killing underground perennial structures. The lag in the spring soil warm-up retards the life cycle of early spring plants jeopardizing their survival. Nutrient cycles and humus formation may be affected by the curtailment of soil-microbe activities. The impact appears to be greater on forest communities when compared to open areas, partially because drifting snow may fill in the tracks in the latter.

Next to traffic and automotive vehicles, snowmobiles are the cause of the largest number of complaints about noise during the winter months. This is due to the fact that snowmobiles at present are inherently noisy and are sometimes used in inconsiderate ways. The noise levels in the ear of the operator is in the range of 100 to 115 dB(A). New snow-

T A B L E    XXXVIII  
EFFECTS OF SNOW COMPACTION BY SNOWMOBILES

	DENSITY	THERMAL CONDUCTIVITY
New Snow	0.17 gm/cm <sup>3</sup>	1.52 x 10 <sup>-4</sup> cal/cm <sup>3</sup> -sec/ <sup>0</sup> C
One Pass	0.26 gm/cm <sup>3</sup>	2.49 x 10 <sup>-4</sup> "
Two Passes	0.36 gm/cm <sup>3</sup>	6.3 x 10 <sup>-4</sup> "

mobiles will be limited to noise levels of 83 dB(A) at 50 ft. by federal legislation. At least one manufacturer has produced a machine which does not exceed 70 dB(A) at that distance. Consequently, future noise levels will be decreasing. It is of interest that the Conservation Council of Ontario proposed maximal noise level of 80 dB(A) at 15 feet.

In addition to annoying people, snowmobilers may harass wildlife at a critical time of year. Some people just want to get closer to see the animal, or chase it. This may exhaust the animal's energy reserves and thus unwittingly tip the balance against wildlife in a period when food is scarce. On the other hand, snowmobile trails are used by wildlife such as deer, to get to a food supply when the snow is deep.

Snowmobiles produce emissions to the atmosphere similar to the automobile. Although these emissions may be somewhat greater on an energy consumption basis, their total impact on air quality is not a problem at present.

#### 5.5.2 Powered Watercraft

In 1965 the boat registrations for 10 H.P. and over were 288,000 in Ontario and is increasing by 20,000 per year. (109)

Outboard engines accounted for over 90 percent of the total, the remainder being inboard gas or diesel engines. Over 98 percent of all outboard in use are of the two-stroke cycle

type.

Due to the inherent design of these engines and their emission characteristics two-cycle engines are more potential polluters than four-cycle engines. Therefore, any study of water pollution should have its greatest emphasis on outboards.

The amount of discharge varies with different makes and sizes of outboards. A 10 to 20% discharge of unburned fuel and oil is quite common.<sup>(110)</sup> Since nearly one billion gallons of outboard fuel are sold annually in North America, at least 100 million gallons of unburned outboard fuel are being discharged every year into the navigable waters. As a result, toxic materials such as tetraethyl leads may accumulate in aquatic plant and fish life.

Recently, at least one major manufacturer was attempting to solve the emission problem by engine modification. It will, however, take about a decade before the majority of the older engines are replaced. By that time many of our smaller lakes may be contaminated.

The Ontario Ministry of the Environment has a research project underway on pollution caused by outboard marine engines.<sup>(111)</sup>

The study indicates that the degree of pollution caused by outboard exhaust emissions is low in areas of moderate use and the effect on aquatic life is not as serious as was reported

before. In waters adjacent to marinas and high use landings, fuel spills related to marine motors use do have an immediate and noticeable effect. The study also indicates that spills evaporate quickly and that the organic load is low. The first sign of pollution in such areas is that fish become tainted, but usually the taint disappears in 7 - 10 days when the fish is removed from polluted waters. Noise pollution and the potential for accidents by the use of motor boats appear to be of more serious concern than water pollution. The study suggested that a power boat pollution index based on horsepower hour/acre feet be developed.

That there is a growing concern among people engaged in certain recreational pursuits in Ontario is borne out by letters which have been received at Queen's Park. The complaints are mainly directed against the use of high-powered boats on the smaller bodies of water particularly for water-skiing. Such complaints usually include the following:

Oily films on the water surface which degrade the water quality for recreation, stirring up of bottom silts which muddies the water, noise pollution, danger to swimmers, erosion of banks and shores as a result of the waves caused by speeding watercraft, adverse effects of waves, noise and other disturbances of fish and wildlife and enjoyment of personal property.

As a result of the continued growth of powered watercraft in

Ontario waters, the problems are likely to increase both in intensity and will also spread to waters not at present accessible. The use of powered watercraft has been restricted in designated waters within conservation areas and provincial parks. Restrictions of the use of powered watercraft, or as to the permitted maximum horse-power, on designated waters outside conservation or park areas should be considered in order to control the effects of high-powered boats on smaller water bodies.

#### 5.5.3 Other Motorized Recreational Vehicles (MVP'S)

Devices on wheels for the wild country include dune buggies, dune cycles, ATV's (all-terrain vehicles), ATC's (all-terrain cycles - 3 wheeled), RTV's (rough-terrain vehicles), swamp buggies, specialized 4-wheel drive automobiles and trucks, trail bikes, etc. These vehicles are driven off-the-normal transportation route and are capable of being driven in, over and through almost any surface area in Ontario from Long Point Marshes to the fragile Arctic tundra. Wide deep and treaded tires or caterpillar tracks support some of these vehicles. Such traction and floatation is required to pull the vehicles through soft sand (often stabilized from erosion by grasses and small shrubs) and to cross marshes (nesting sites of waterfowl) and shallow water (spawning beds or habitat for fishes).

The environmental impact of the use of these recreational and transportation vehicles include compaction of soils, churning up of soils susceptible to erosion, killing of grasses and shrubs preventing erosion, damage and death to trees, shrubs and other vegetation, oil spills and emission of exhaust gases, noise, fire hazard, littering, trespass, disturbance of nesting birds and wildlife populations. To prevent such environmental impacts, the recreational use of such vehicles will have to be directed to selected designated areas.

#### 5.5.4 Air Cushion Vehicles and Aircraft

Air cushion vehicles suitable for recreational use, and under \$2000.00 purchase price, are now on the market.

The environmental impact of air cushion vehicles and aircraft is concerned mainly with noise, exhaust emissions into the atmosphere and oil spills on land and water, usually during refuelling and maintenance operations. The major impact of the recreational use of these vehicles will be in the disturbance of breeding, feeding, rearing and resting habitats of fish and wildlife.

#### 5.5.5 Summary

The main problem of the use of all recreational vehicles in general is not so much related to the use of energy or fuel

per se, but rests in the way of how a growing number of people are using their machines. Due to the vastness and inaccessibility of many areas of the Province, little, if any control can be effectively exercised. As a result, irreversible damage to land, water, and wildlife may be expected to increase, unless regulations are introduced to protect our environment from abuse by irresponsible operators.

#### IV. ENERGY AND THE LAW

##### I. CURRENT LEGISLATION

##### 1.1 Air Pollution

##### 1.1.1 Province of Ontario

Ontario has enacted the most comprehensive air pollution legislation in Canada. Control is exercised under The Environmental Protection Act, 1971,<sup>(112)</sup> which also includes legislation for water, solid waste, noise and pesticide abatement and control. The Air Management Branch, part of the Ministry of the Environment, enforces the Act through a set of air pollution regulations.

Emission standards for 80 contaminants are stated in terms of ground-level concentration at the point of impingement. The same regulation includes the desirable air quality for 27 air pollutants. Many other contaminants have been defined. Specific regulations govern emissions from automobiles, asphalt plants and ferrous foundries. A sulfur content in fuel regulation is limited to Metropolitan Toronto. Although there is no **criterion** for reactive hydrocarbons in ambient air (reactive hydrocarbons are the species which may produce photochemical smog) in Ontario, it is possible that either the Federal or Provincial Governments might introduce one in the future. This **criterion** would affect the refining and automobile industries. An Air Pollution Index<sup>(113)</sup> system is in force in 4 areas.

Metropolitan Toronto, Hamilton, Windsor and Sudbury. The Index is used to reduce harmful emissions, depending upon adverse meteorological conditions. The Index is a 24-hour running average of sulfur dioxide and solid particulate values and has been determined from past air pollution episode conditions in other parts of the world.

Table XXXIX compares air quality objectives for Ontario with values announced by Environment Canada, and with the Federal U.S. standards. Ontario's program is consistent with the uniform air quality objectives throughout North America. The Act also specifies community noise as an environmental pollutant. Although it will limit the noise levels of devices which require energy for their operation, (vehicles, air conditioners, mowers, snowmobiles, motorcycles, etc.) its regulations will not greatly impact the energy industry or significantly alter energy consumption patterns.

#### 1.1.2 Federal Government

The Clean Air Act, 1971 (Bill-C-224)<sup>(114)</sup> provides for air pollution control agreements between provincial and federal governments. It could also provide for funding of provincial programs in order that they agree with standards set by the federal government.

Federal installations, which have been exempt from provincial requirements, will be required to meet federal standards. These

TABLE XXXIX

## NORTH AMERICAN AIR QUALITY OBJECTIVES

in mass units ( $\mu\text{g}/\text{m}^3$ )  
with volume units (ppm) in brackets

	Federal Max. <u>Desirable</u>	Federal Max. <u>Acceptable</u>	U.S. <u>Secondary</u>	ONT. <u>OBJECTIVES</u>
<u>Sulfur Dioxide</u>				
1 hr	450 (0.17)	900 (0.34)	1300 (0.50)**	650 (0.25)
24 hr	150 (0.06)	300 (0.11)	260 (0.10)	260 (0.10)
1 yr	30 (0.01)	60 (0.02)	60 (0.02)	60 (0.02)
<u>Particulates</u>				
24 hr		120	150	120
1 yr***	60	70	60	60
<u>Carbon Monoxide*</u>				
1 hr	15 (13)	35 (30)	40 (35)	36 (30)
8 hr	6 (5)	15 (13)	10 (9)	16 (13)
<u>Oxidants</u>				
1 hr	100 (0.05)	160 (0.08)	160 (0.08)	200 (0.10)
24 hr	30 (0.015)	50 (0.025)		
1 yr		30 (0.015)*****		
<u>Hydrocarbons</u>				
3 hr		none	160 (0.24)	None

\*  $\text{mg}/\text{m}^3$ 

\*\* 3 hr. max.

\*\*\* geometric mean

\*\*\*\* arithmetic mean

may or may not be as stringent as those of the provinces.

There is authority in the legislation to:

- (1) set national air quality objectives
- (2) set national emission standards where the emission could cause a national health hazard, or comply with the terms of an international agreement, such as those involved in trans-border pollution
- (3) regulate the composition fuels imported into or produced in Canada, and
- (4) set national emission guidelines.

## 1.2 Water Pollution

### 1.2.1 Province of Ontario

The Environmental Protection Act, 1971 provides that no person shall add any substance to water that will or is likely to cause injury to any person, animal, bird or other living thing. The extensive powers of the former Ontario Water Resources Commission (OWRC) have been transferred to the Ministry of the Environment.

There are other Provincial Acts which contain numerous provisions and regulations which, although not expressly prohibiting water pollution, can be applied to prevent or minimize it. They are as follows:

- (1) The Municipal Act
- (2) The Public Parks Act
- (3) The Public Health Act

(4) The Lakes and Rivers Improvement, Public  
Lands and the Provincial Parks Acts

(5) The Conservation Authorities Act

Members of the Ministry of the Environment work with members of the Ministries responsible for the above-mentioned Acts in maintaining surveillance of any surface and groundwaters in Ontario.

1.2.2 Federal Government

The Navigable Waters Protection Act provides for the control of water quality in waters used for navigation and shipping. The Inland Fisheries Act provides for the control of water quality insofar as it concerns the preservation and conservation of fish. The Indian Act contains provision for the regulation of reservation waterways. The Migratory Birds Convention Act prohibits pollution of waters frequented by migratory birds or waters flowing into such waters. Finally, the Canada Water Act, the most regulatory of Federal water pollution legislation, permits the Federal Government to designate, as a water-quality management area, any body of water where there is significant national interest, and, as such, maintains water quality management in all areas of the country.

1.3 Radioactive Emissions

The authority, in Canada, which controls all uses of radio-

active materials including the operation of nuclear power stations is the Atomic Energy Control Board (AECB) assisted by the Reactor Safety Advisory Committee (RSAC). The Reactor Safety Advisory Committee is specifically selected for each individual reactor and reviews with the Board's staff officers all aspects of the proposed station from preliminary concepts and proposed site through design and commissioning to routine operation. The RSAC consists of experts in many disciplines and representatives from other interested regulatory authorities. For a reactor to be sited in Ontario, the Ministries of the Environment, Labour and Health would be represented, along with the Medical Officer of Health for the County or areas adjacent to the reactor site.

2. International Programs

Many international programs have been created in the pursuit of uniform environmental goals or standards and joint action on common international pollution problems. Canada and Ontario participate in many of these programs, but a bilateral program with the U.S. is of particular importance. The United States and Canadian Governments are working together (1) to restore the quality of the Great Lakes -- a vital asset for a large segment of the population on both sides of the boundary and

(2) to reduce the transboundary flow of air pollutants.

Ministers of both countries agreed to set up a Joint Working Group to study and evaluate the Great Lakes problem.

The Group began to study ten major problem areas and by April 1971, issued a report containing its recommendations.<sup>(26)</sup>

It urged the two Federal Governments to agree to adopt common water-quality objectives for the Great Lakes, to agree to programs for attaining the objectives, and to give the IJC authority to monitor these efforts.

Subsequently, the two Governments agreed to adopt the report of the Joint Working Group and to complete a Great Lakes Water Quality Agreement embodying the recommendations by the end of the year. The agreement will specify measures to control Great Lakes pollution by 1975, which may include regulations regarding thermal-waste disposal.

The International Joint Commission has also been active in the evaluation of joint air-pollution problems.<sup>(115)</sup> Recently, the Air Pollution Control Office of the U.S. Environmental Protection Agency issued a set of proposed standards. These standards are slightly higher than those already adopted by Ontario. At this time, Ontario will continue to use the lower values and develop abatement strategies to meet the more stringent objectives.

Air pollution in the Windsor-Detroit and Sarnia-Port Huron areas has caused concern for many years. The International Joint Commission, at the request of both governments, has carried out comprehensive investigations of the inter-boundary flow of air pollutants which is reported in reference 115. The study recommended that control agencies, in both countries, accelerate their abatement programs to bring all sources into compliance with the law. Costs for control of SO<sub>2</sub> and particulate matter only in these two areas was estimated at over \$65 million. A committee composed of the heads of the air-pollution control programs for the State of Michigan, Wayne County and the Province of Ontario has been established to achieve these goals.

Although the IJC program is active, it is probably fair to summarize it by saying that progress in the form of remedial action is slow in coming. The U.S. government has not yet provided its share of resources needed to carry out the recommended program.

3. Other Legislation in North America

There are a countless air, water and radiation pollution regulations in the United States. Only some of the emerging trends pertaining to energy use are discussed here.

- (i) Environmental Impact Statements<sup>(13)</sup> require that any group or agency of the U.S. federal government, proposing

legislation or planning to undertake an action "significantly affecting the quality of the human environment", must file an impact statement. The statements must describe the legislation or action, its impact, and the alternatives considered. Before filing, the statements must be circulated by that agency to the public and to appropriate Federal, State, and local environmental agencies. Comments received on the draft statement become a part of the public record. The Administrator of EPA has the independent responsibility for reviewing and commenting on the environmental impact of all proposed Federal activities or legislation.

Over 20 U.S. federal agencies have established internal procedures for preparing impact statements. Some agencies, for the first time, have explicitly incorporated environmental considerations into their decisions.

The system is not yet working as intended. Lack of environmentally-trained personnel and the difficulty of changing established decision-making patterns are still problems. Too often, the environmental statement is written to justify decisions already made, rather than to provide a mechanism for critical review.

Consideration of alternatives is often inadequate, and the ultimate alternative i.e. "taking no action at all because of the environment" has rarely been considered. There is also the difficulty of any group in engaging in public self-criticism.

The value and completeness of these statements varies drastically from agency to agency. Some have been severely criticized as superficial, incomplete, incompetent and misleading. At the other extreme, the U.S. Department of the Interior<sup>(116)</sup> has adopted an elaborate procedure calling for consideration of about 10,000 items in completing a 100 by 100 matrix and assessments must be made for any area, in which there is an environmental impact.

Although the requirement for environmental impact statements, which are made public, has its shortcomings, the basic idea is felt to be good. Various organizations of the Ontario government now use or advocate this concept in one form or another. It is strongly suggested that Ontario establish a policy of requiring environmental impact statements to be completed and evaluated by all Ministries before new programs are implemented. The approach adopted, should profit from the initial shortcomings of the

U.S. program and could be employed by all Ontario government organizations uniformly. It should not be restricted to assessment of the impact on energy use, but applied to all activities which affect environmental quality.

- (ii) Power Plant Siting legislation has also been recently proposed. Under the proposed legislation in the U.S., federal government decision-making on siting of power plants (exceeding 300 MW capacity) would be vested in State and/or regional site certification agencies.<sup>(13)</sup> In the absence of such an agency, or when it fails to act or resolve local differences, the proposed bill would put the final decision in the hands of an ad hoc 3-man arbitration panel, which would have strong siting approval powers, including modifying environmental regulations.

Also included in the proposed legislation, the utilities would be required to identify and upgrade, annually, their regional expansion plans 10 years in advance of, and the plans for specific sites 5 years prior to, construction. These plans should include a site inventory, as well as environmental impact statements for each site. Two years before construction is to start, the

utilities would be required to submit a detailed proposal and an environmental review for the site.

The intention of these long-time intervals between planning and construction is to provide plenty of time for the public and other agencies to assess the proposed plans and to avoid costly last-minute court fights.

This proposed legislation has been apparently directed to cure problems of a system, that does not exist in Ontario -- the existence of a great many privately-owned companies and a few publicly-owned companies, a wide variety of state siting legislation, increasing public pressure to have a voice in siting and a federal government trying to fill voids, left by some states and desiring a uniform national policy.

Best of all, the legislation provides a forum where interdisciplinary representatives from responsible government agencies, must evaluate their parochial departmental interests against the public need, explore the alternatives, and arrive at the best informed decision. An initial step in this direction has been taken by establishing a Siting Task Force and working in close cooperation with other government agencies.

The experiment of the private utilities in sharing their fact-finding and decision-making processes with the public has been met with varying degrees of acceptance. The experience of Northern States Power Company is especially encouraging. It serves to show that the public (consumers and conservationists) can work constructively and with an open mind in helping the utility in siting its power plants.

- (iii) Power Plant Emission Limits have recently been established by EPA in the U.S. <sup>(117)</sup> All new electrical generating plants with over 250 million Btu/hr heat input will not be allowed to emit pollutants in excess of the following:

Solid Particulate Matter (Dust and Fly-ash)	0.10 lbs/million Btu input
Sulfur Dioxide	0.80 (oil) or 1.2 (coal) lbs/million Btu input
Oxides of Nitrogen	0.20 (gas) or 0.30 (oil) or 0.70 (coal) lbs/million Btu

The existing coal-fired Ontario Hydro plants could not achieve the  $SO_2$  limit without using coal with a lower sulfur content than is presently being used. Limits such as these will not ensure improved air quality in the long-term, because the total imposed pollutant burden will continue to increase as additional plants are added.

Recently, California has adopted a new and more restrictive regulation for the emission of the oxides of nitrogen. (118)

(iv) State of California - Rule 68

"A person shall not discharge into the atmosphere from any non-mobile, fuel-burning article, machine, or equipment or other contrivance, having a maximum heat input rate of more than 1775 million British Thermal Units (Btu) per hour (gross), flue gas having a concentration of nitrogen oxides, calculated as nitrogen dioxide ( $\text{NO}_2$ ) at 3% oxygen, in excess of that shown in the following table."

Nitrogen Oxides  
Parts per million parts of flue gas

Fuel	Effective date	
	December 31, 1971	December 31, 1974
Gas	225	125
Liquid or solid	325	225

The 1974 limits will require  $\text{NO}_x$  control measures at least in the form of combustion modifications. It seems relatively certain that such measures will spread

across the U.S. and perhaps into Canada in the next decade. The present power plants emit about twice this concentration of  $\text{NO}_x$ .

- (v) Sulfur Emission Taxes have also been proposed by the EPA in the United States.<sup>(13)</sup> The charge would be levied on sulfur emitted into the atmosphere from combustion or distillation of fossil fuels. To the extent that sulfur is removed from fuels, no payment of the charge would be required. The funds generated by this charge would enable the U.S. Government to increase programs to improve the quality of the environment with special emphasis on development of technology to reduce sulfur oxide emissions and programs to develop adequate clean energy supplies. This measure is intended to provide, both the incentive for  $\text{SO}_2$  abatement and the means for doing so. This abatement strategy has little appeal in Ontario, because it would largely amount to the government taxing itself. It is more direct for the government to decide that  $\text{SO}_2$  emissions are to be reduced and then do what is necessary to achieve this policy. Such a tax, however, might provide a strong incentive for the reduction of emission from industrial sources.

## V. LONG RANGE PROBLEMS

### 1. Possible Global Climate Changes

In attempting to predict any long-range environmental problems, the lack of quantitative and predictive research in this field leads to a large amount of uncertainty about future conditions. There are primarily three areas, where possible climatic changes could occur, which are being discussed and debated at present.

#### 1.1 Carbon Dioxide Build-up

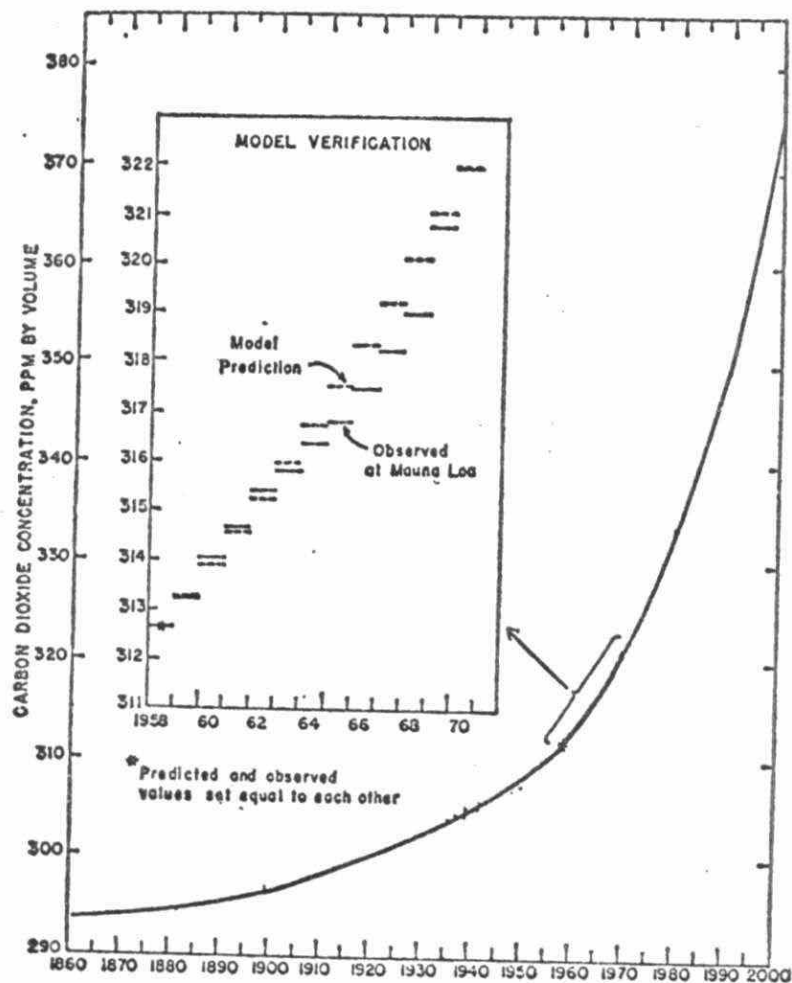
Carbon dioxide is one of the products of combustion of fossil fuels. Over the last few decades the average concentration of  $\text{CO}_2$  in the atmosphere has increased at the rate of 0.2% per year.<sup>(10)</sup> Estimates of the increase of  $\text{CO}_2$  in the atmosphere have been made by Machta<sup>(119)</sup> and are shown in Figure 30. The steep rise is due to man's steadily increasing use of combustion.

Carbon dioxide will effectively transmit the ultra-violet radiation from the sun but will selectively absorb the longer wavelength radiation from the earth. Consequently, as the atmospheric  $\text{CO}_2$  concentration increases, the earth will tend to become warmer.

It has been estimated, that an increase in the carbon dioxide concentration from 320 to 375 ppm will occur by 2000 and will warm the surface layer of the earth by about  $1^\circ\text{F}$ . While this change is unlikely to be critical, it is apparent that a continua-

FIGURE 30

Model calculation of atmospheric  $\text{CO}_2$  from combustion of fossil fuels.



tion of  $\text{CO}_2$  production would lead to large increases in the  $\text{CO}_2$  concentration. Manabe and Wetherald<sup>(12)</sup> suggest that a doubling of the concentration of the gas could lead to a  $5^\circ\text{F}$  increase in world temperature which "could trigger other warming mechanisms and possibly lead to irreversible effects." The consequences of such an event are so great that it should not be dismissed from our planning even though it may be a century or more in the future.

## 1.2

### Waste-Heat Production

The amount of heat input into the environment depends directly upon the energy used. Heat will always be produced and as power generation moves from fossil fuels to nuclear fuels the quantities will increase. In addition, heat is released into the environment from industrial, transportation, domestic and commercial sources. The 4000 square miles of the Los Angeles basin now generate in thermal power, the equivalent of more than 5 percent of the solar energy absorbed at the ground and this amount is expected to rise to 18% by 2000.<sup>(120)</sup> Individual cities, with their high level of energy use, have higher downtown temperatures (see Table 111) and are covered by overhead three-dimensional heat islands, which act as chimneys to expel pollutants (Figure 2). Both the "useful" and the "waste" energy eventually find itself heating the environment and one major study concludes that they

"see the possibility of climatically significant changes on a regional scale in the near future" and that "on a local scale, this influence is already very large."<sup>(121)</sup>

Probably the most significant and far-reaching effects of our continuing rate of growth production will be on a global scale. According to the report of the Study of Man's Impact on Climate<sup>(12)</sup> -- "there is a distinct possibility that a temperature rise associated with the anticipated injections of heat and CO<sub>2</sub> into the atmosphere in the next century would result in melting of Arctic ice." The reduction in the earth's surface reflectivity could cause more heat to be absorbed with a consequent acceleration of the process. In addition, there may be large changes in precipitation, wind systems and ocean currents, which could create deserts in formerly productive areas and have other serious biological and social consequences.

### 1.3 Turbidity

It has been estimated that between 5 and 45 percent of the particulate matter in the atmosphere is produced by man.<sup>(122)</sup> Much of the man-made particulate is directly emitted during combustion or else is the product of gases produced from the industrial and domestic consumption of fuel, the internal combustion engine, the incineration of domestic waste and agricultural burning. Other particles are emitted during some industrial and mining processes and indirectly from some food production practices, such as ploughing and overgrazing of arid or semi-arid lands.

Particulate matter in the atmosphere may cause several dramatic implications, such as scattering of sunlight, preventing it from reaching the earth's surface, affecting the formation of clouds, snow and rain, thus changing the precipitation and temperature balance of the earth. The consensus opinion is that this will produce a cooling of the earth and some claim it will balance the effects mentioned above.

It is most unfortunate that more information is not available on the long-range environmental effects, for policy makers are faced with the problem of making decisions under conditions of uncertainty, both with respect to the absolute necessity of making a very major change and with respect to the time at which this change must be made. However, it is unreal to assume that we will be able, some time in the future, to balance global warming trends by cooling trends and maintain the earth's natural thermal balance. It is not too early to recognize these possibilities and to promote additional work directed toward a better understanding of man's impact on the climate.

## 2. Predicted Consequences of Exponential Growth

Many studies have demonstrated that nearly all of man's activities (population, power generation, industrial growth, transportation growth, food production, use of resources, production of waste products, to name a few) grow in an exponential way.

This is, they double time and time again every few years. This growth has not created serious problems in the past because the limits of the earth's capacity to sustain the growth have not yet been reached. However, there is growing concern that certain limits are now being approached and we must soon face the reality of living in a closed system. It is imperative to look ahead and try to predict what sort of crises may occur and then try to devise means of avoiding them. This is a task fraught with uncertainties arising from lack of knowledge of our complex system and the unpredictable reactions of humanity toward change.

Various growth predictive models have been devised in the past. Most of them have underpredicted what actually occurred because they were based on near-linear projections. Quite recently, Forrester at M.I.T. has devised a very comprehensive computer model which attempts to account for the interaction of many complex inter-relationships influencing world-wide growth.<sup>(123)</sup> It is probably the most ambitious attempt at predicting the future undertaken to date.

Previously, Forrester has modelled several other complex processes and his computer modelling of urban dynamics<sup>(124)</sup> is particularly well-regarded by urban planners and is currently influencing urban planning. Consequently, his new effort in predicting man's future in a much broader sense in World

Dynamics<sup>(123)</sup> is being widely discussed and debated. His complex computer model yields an overall prediction of the course of world events.

In analyzing the world system, he considers 5 parameters (1) population, (2) capital investment, (3) natural resources, (4) capital devoted to agriculture and (5) pollution. These parameters are considered as parts of "feed-back" mechanisms. The influence of 52 separate factors and their inter-dependence are taken into account. Only the pollution aspects of this model are considered here in any detail. The pollution subsystem is shown in Figure 31. Population and capital investment influence pollution levels by acting on the rate of pollution generation. The rate of pollution generation is assumed to increase linearly with respect to increasing population. Increased capital investment increases pollution generation through increased power generation, increased processing of raw materials, increased industrial wastes, increased use of fertilizers and chemicals in agriculture, and by several other factors.

The ways in which all of the factors, considered, actually influence pollution is not known. Consequently, Forrester makes broad assumptions about these influences which are currently being questioned, debated and investigated. For

Factors  
contributing  
to pollution:

# The Pollution Cycle

Factors  
affected by  
pollution:

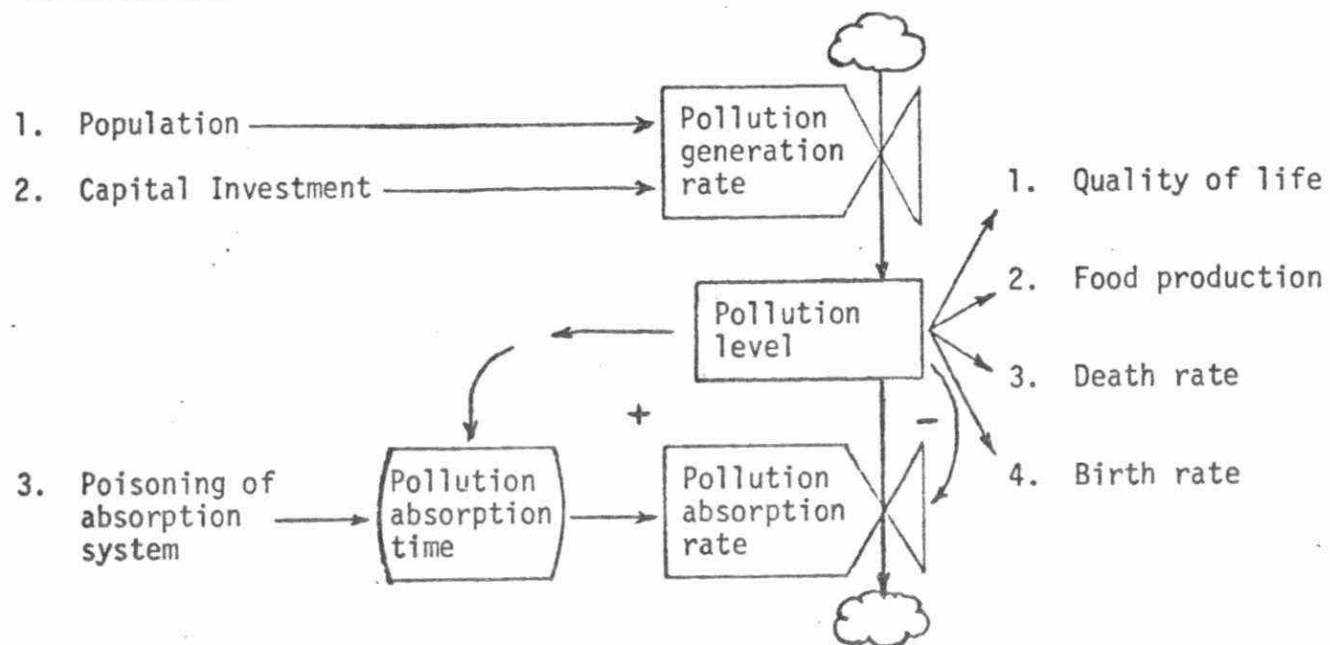


Figure 31 The Pollution System According to Forrester

example, he assumed graphic relationships from which the following observations are drawn:

- (1) Pollution-generation rate is considered to increase 8-fold when capital investment increases 5-fold.
- (2) Food production, decreases to 50% of the present level if pollution increases 25 times the present level.
- (3) Death rate increases to 10 times the present rate if pollution increases 60 times the present level.
- (4) Birth rate decreases to 50% of the present rate if pollution increases 25 times the present level.

All of these assumptions may be immediately questioned. He bases them on observations of the general trends. Consequently, the levels and time estimates predicted by Forrester are probably not accurate. At this time, one should only consider the main thrust of his work, and the trends his model predicts rather than be concerned about what particular decade a certain trend may develop.

Many important mineral resources are rapidly approaching depletion. Table XL gives the numbers of year for which the known reserves will last at the 1970 usage rate and at the continued

exponential rise in usage rate. (125)

According to Forrester's model, when our present-day system is projected into the future without any changes, depletion of natural resources is found to be the growth-limiting factor (see Figure 32). Population reaches a maximum and declines slowly in the next century. Pollution increases to several times its present level but does not limit growth. Table XL suggests that we may indeed be on the path depicted in Figure 32.

If technology finds ways to reduce the usage rate of natural resources through the wider use of plastics or by recycling, the computer model predicts that pollution emerges as the limiting factor (Figure 33). In this case, however, the turning point is followed by catastrophic decline in population in the next century.

In a similar way a number of other strategies for the future, are often discussed.

- (a) continued economic growth (increased capital investment)
- (b) reducing the birth rate
- (c) technological solution to pollution problems
- (d) increased global food production

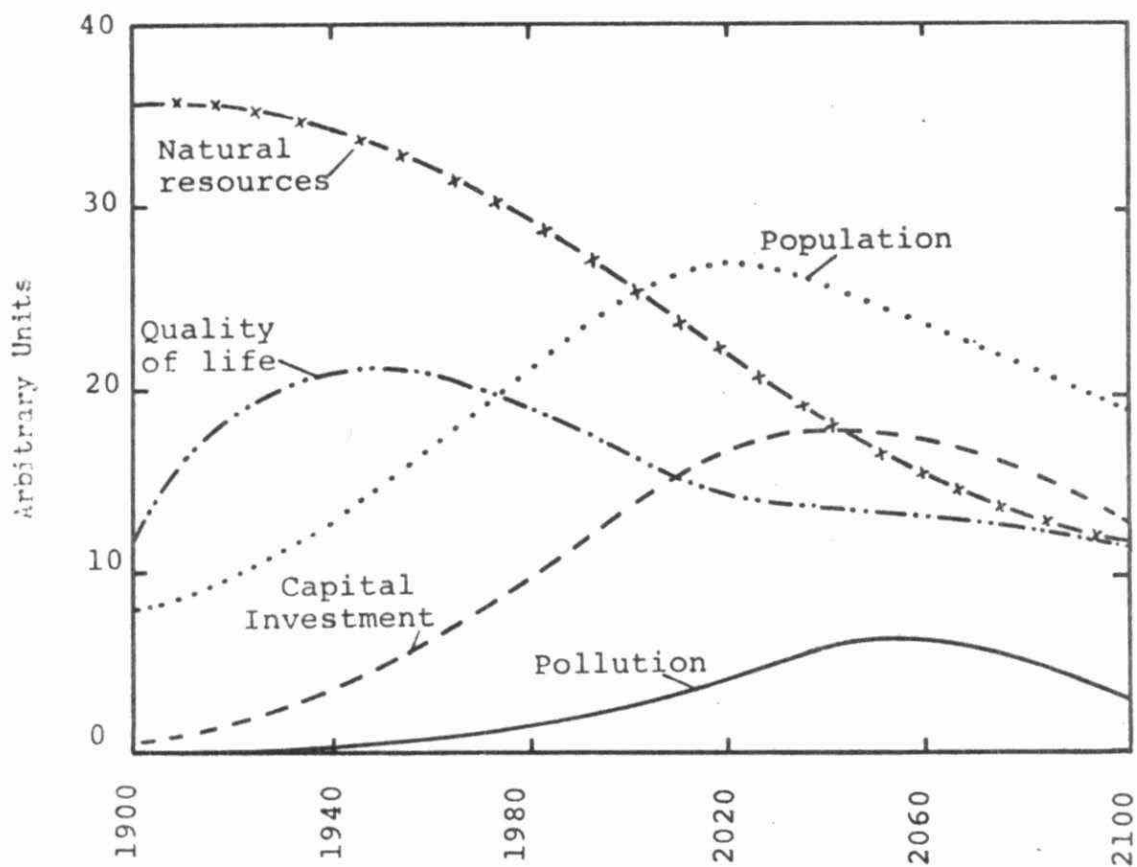
all give rise to a "pollution crisis" similar to that depicted in Figure 33 in the next century.

TABLE XL

## Depletion Times for Mineral Resources

<u>Metal</u>	<u>Time to Deplete Reserve at 1970 Rate of Usage (Years)</u>	<u>Time to Deplete Reserve if 2.5% Increase in Usage Rate Continues</u>
Mercury	14	13
Lead	18	15
Platinum	19	16
Gold	19	16
Zinc	20	17
Silver	23	18
Tin	25	19
Copper	40	28
Tungsten	45	31
Molybdenum	100	51
Nickel	130	59
Aluminium	160	65
Cobalt	160	65
Manganese	160	65
Iron	400	98
Chromium	560	110

Figure 32 - World system projected into the future under present conditions.



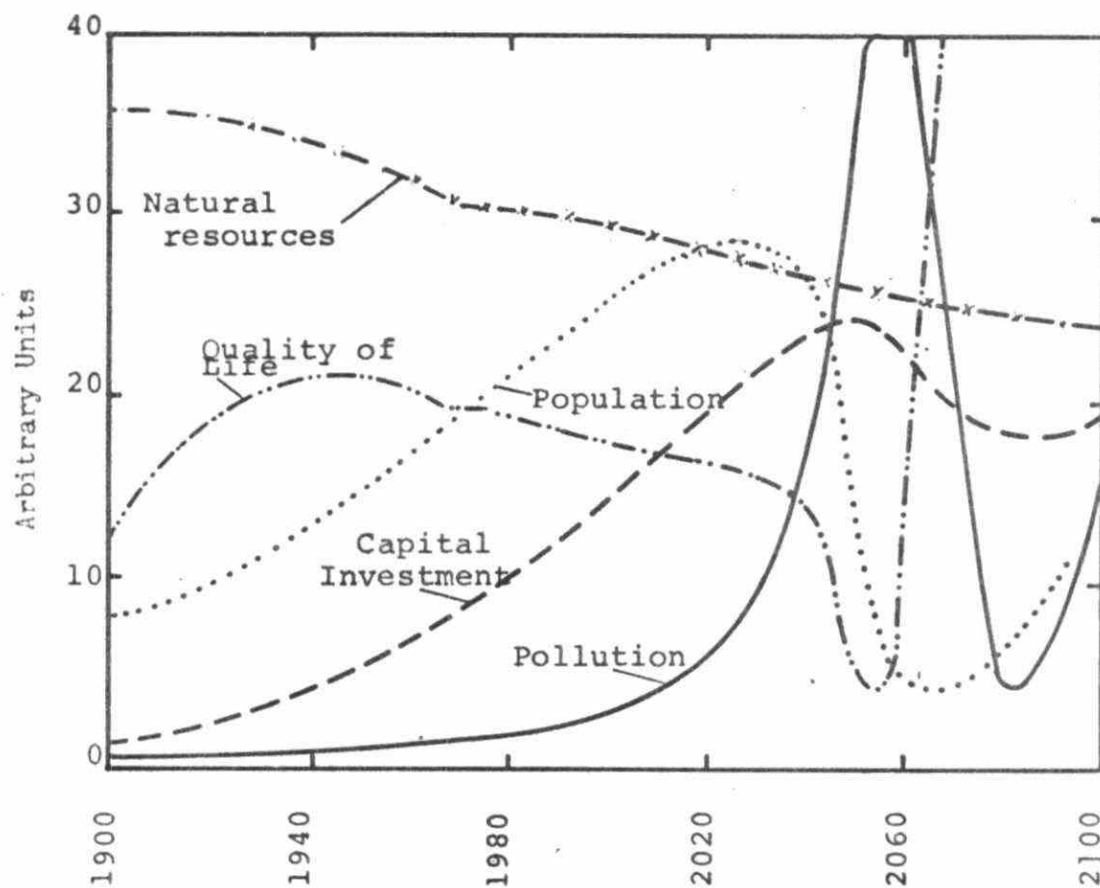
It is interesting to note, that attempting to solve the pollution crisis shown in Figure 33 by application of technology to reduce pollution generation, still produced a pollution crisis but at a later date. In this case, increased industrial growth ultimately outpaced pollution control. As a result, more people suffered the ultimate consequence.

All of the catastrophic changes predicted by Forrester's model result from rapid pollution increases at some point in time. The assumption made about the influence of pollution may unrealistically weight this factor too strongly. Considerably more thought and research of his assumptions and the formulation of more accurate ones is clearly warranted. Because his present calculations illustrate that pollution is a powerful triggering influence, the pollution subsystem in his model deserves immediate attention. Moreover, prevention of a pollution crisis involves control of many factors besides those directly related to the environment.

Only when an unrealistic model, in which it was assumed that natural resources are infinite and pollution does not exist, did over population emerge as the growth-limiting factor.

Forrester has also employed his computer model to suggest strategies for avoiding the fates shown in Figures 32 and 33.

Figure 33 - Pollution crisis results when natural resource usage rate decreased 75% in 1970.



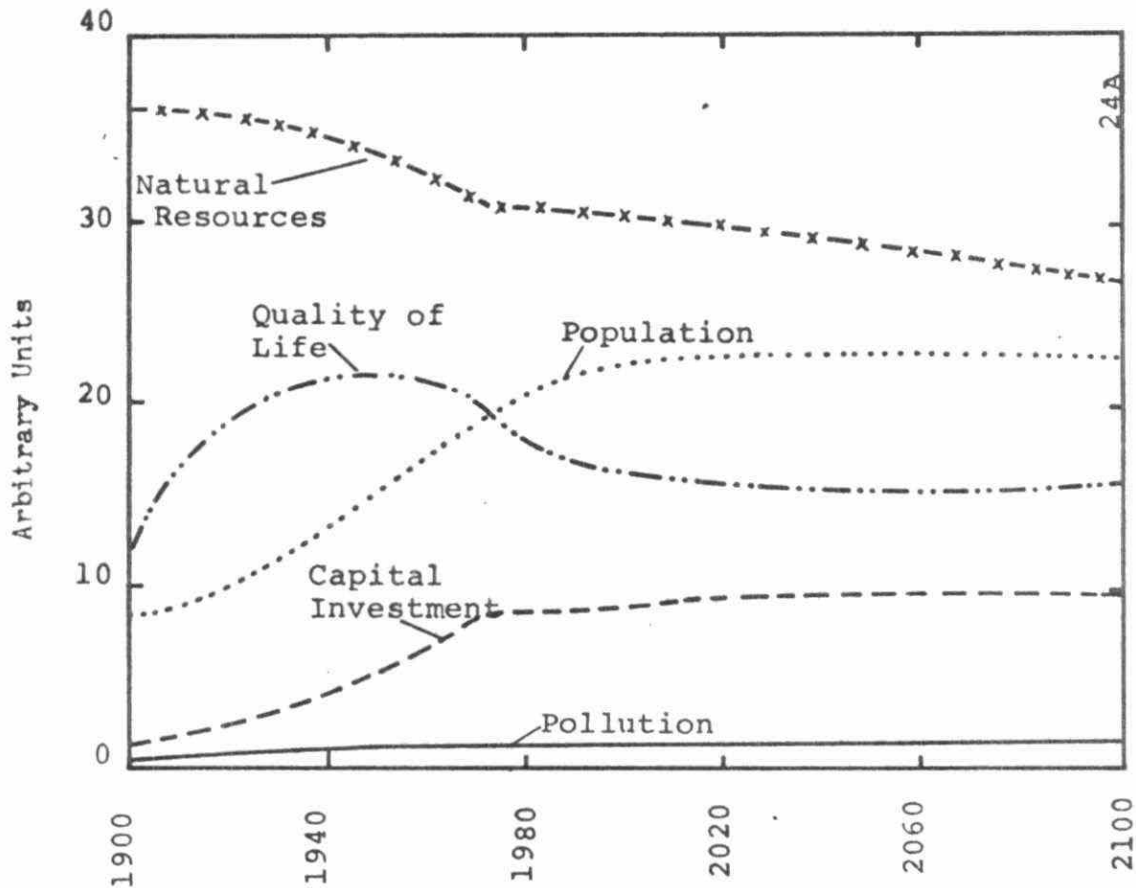
To date (126) he has been able to produce a kind of steady-state system only by making relatively drastic changes in his input starting in the year 1970. The changes needed were:

- (a) natural resource usage rate reduced 75%
- (b) pollution generation rate reduced 50%
- (c) capital investment reduced 40%.

These changes resulted in a decreased food availability and a decreased birth rate, thereby inducing stability through hardship. They result in a type of "zero-growth" society shown in Figure 34. The concept of "zero-growth" has also been described in detail in another study conducted for the Advisory Committee for Energy. (127)

Obviously, the changes described above would be difficult to institute and in fact, since they represent imposed hardships, they may not be justifiable. The growth-oriented business world would resist even relatively minor reductions in capital investment and resource usage, let alone the staggering values required by Forrester's computer model. The consumption of energy resources is not likely to be an ultimate limiting factor for growth, because of the essentially unlimited supply of energy available from nuclear sources.

Figure 34. Steady state induced by reducing natural resource usage rate 75%, pollution generation rate 50%, and capital investment 40% in 1970.



There is evidence that there may be a period of energy shortage in the next two decades during the conversion from fossil fuels to atomic sources. However, the shortage will be alleviated if breeder reactors come into successful operation in 1985 as expected.

The crisis predicted by Forrester, which will result from continued exponential growth, can be avoided only by arriving at a steady state in the world system. Three basic actions will be required to move toward a steady state:

- (1) Reduce usage rate of natural resources
- (2) Reduce and redirect capital investment
- (3) Decrease birth rate.

Many difficulties can be anticipated in changing from a policy of growth to one of steady-state.

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